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9. ABSTRACT

Part III of the Agricultural Sector Planning Report presents a bried description of the physical characteristics, the soioeconomic structure, and the institutional setting of the Korean agricultural sector. This is followed by an overview of: the perspective and values held by Korean decision makers with respect to the agricultural sector and its relation to the national economy; the general set of problems that has determind the scope of the sector analysis and modeling effort reported earlier; the current broad design of the Korean Agricultural Sector Model System (KASM) in terms of its disaggregation levels, component models, and linkages; and the broad policy areas addressable by the sector models. Use of this KASM to analyze alternative development patterns of Korean land and water resources has providéd a guide to potential supply and demand for food in Korea. The analysis is highly dependent on several key projections of yields, population, and per capita consumption. Sensitivity testing of key variables was accomplished and documented in the study report for the Korean government. The approach used in the study incorporates a polyperiod LP model and KASM to define and evaluate various development in Korea will be able to use KASM with the more sophisticated technology change component discussed in the report. Change incorporates the relationships now included in the polyperiod LP model, plus numerous other relationships. It can also be used in conjunction with other KASM components or run independently.

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AGRICULTURAL SECTOR PLANNING

A GENERAL SYSTEM SIMULATION APPROACH

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PREFACE

For as long as governments have existed, public sector decision makers have searched for better methods of planning and monitoring the performance of national economies and their subcomponents. In recent years, interest in many countries has focused on comprehensive and integrated sectoral planning and performance monitoring. Government officials in these countries are searching for better tools and techniques to assure more consistent and higher quality analytic input into their decisions. Some have turned to computer-based models as a partial answer to their needs. Many, however, are reluctant to make the sizable investment required for large and complex computer-based modeling efforts.

The arguments against computer-based modeling largely follow the line that the techniques and methodologies employed are generally not understood by decision makers, often do not include all the information necessary to a comprehensive analysis of the problem under consideration, and sometimes lead to unworkable prescriptions for action. Such arguments, in too many cases, have been justified.

The authors contributing to this book argue that it is possible, and in many cases highly desirable, to develop decision-making systems that include an investigative capacity to carry out analytical and monitoring functions with computer-based models as an integral part of the system. The authors, with widely varying backgrounds and experiences, through a series of fortuitous events became involved in working together on a project funded by the U.S. Agency for International Development (USAID) and carried out by Michigan State University in cooperation with the Ministry of Agriculture and Fisheries, Republic of Korea. This book is about the set of experiences and the lessons learned from this project. As such, it is as much about people and institutions as it is about models. The book should be useful to a wide range of scholars, students, administrators, policy analysts, planners, and decision makers interested in better approaches to more effective public sector decision making.

Although the work in Korea is depicted in some detail, the authors intend these descriptions to be viewed by the reader as a case example of the application of the general system simulation approach toward providing investigative input into the decision process. The Korea example focuses on national-level decision making with respect to agricultural sector development. But the lessons learned from this experience and the conceptual framework of the approach are applicable in a variety of decision-making contexts, subject matter foci, and geographic locations.

We wish to acknowledge the contributions and support provided by Francis C. Jones, both as project monitor during his tenure as Food and Agriculture Officer, USAID/Korea, and as one of the authors of this book after his retirement from USAID. His death in the spring of 1977 saddened us all.

It is impossible to individually acknowledge the contributions by the many people and institutions who have been a part of the projects upon which this book is based. To them the authors of this book owe a heartfelt debt of gratitude. Special acknowledgment and appreciation are due the institutions with which the authors are affiliated for providing them the opportunity to participate. We also specifically acknowledge the Government of the Republic of Korea for its contributions and cooperation, and the U.S. Agency for International Development for the funding which made both the projects and the book possible.

Particular thanks are due Michael H.B. Adler, Duck Young Rhee, Dong Hi Kim, and Man Jun Hahm for their interest, support, and participation. Appreciation is due Donnella Meadows whose excellent review and critique of the draft manuscript were extremely useful in developing this final version.

Finally special thanks go to Bert Pulaski, project administrative officer, who released us from untold logistic and administrative details and kept us solvent; to Kathleen Schoonmaker, who edited and managed the manuscript through the publication process; to Larry Senger, who assisted in the many steps from draft manuscript to published book; and to our secretarial staff — Judy (Pardee) Duncan, Edith Nosow, Kyong Soo Kim, and Sonia Brundage — for a difficult job well done.

George E. Rossmiller
Editor for the Team

Michigan State University
January 1978

INTRODUCTION

The purpose of this volume is to explain the general system simulation approach as a viable basis for providing input to planning and policy decision making in agricultural sector development. We do this through discussion of the philosophic orientation of the approach, its eclecticism with respect to modeling techniques and types and sources of data, its relationship to the decision-making process, and the establishment of its credibility with decision makers. We also discuss the prerequisites for institutionalization and use of the general system simulation approach for agricultural sector development planning and policy analysis within the agricultural decision structure of a national government. The development and institutionalization of the approach in Korea is detailed and conclusions are drawn about its transferability and preconditions for its use in other developing (or developed) countries.

A wide and varied audience for this volume is anticipated. It should be of particular interest to:

1. Agricultural sector development decision makers at the national level interested in improving the quality of their planning, policy formulation, program development, and project design, implementation, and evaluation
2. Agricultural sector development staff and policy analysts searching for more useful and comprehensive approaches to problem-solving analysis
3. Students of the systems approach interested in methodology and application of systems analysis to socioeconomic problem areas

4. Students of economic development within and outside the academic community who are interested in alternative methodological approaches to agricultural sector development problem solving
5. Students of political and institutional development interested in the problems, requirements, and process of integrating the use of quantitative analysis into the decision-making structure of developing (or developed) countries

In writing for such a diverse audience, we run the risk of probing too deeply in some areas and not deeply enough in others to satisfy any given reader. For those of you who are quantitatively oriented and are interested in a more in-depth mathematical treatment of the models, we can only refer you to the technical documentation by the project team [1, 2, 8, 30, 40, 115]. We urge those who find some of the concepts and the occasional mathematical exposition to be laborious simply to skip over those sections or equations. In doing so, most readers will find the general meaning still apparent.

The book is organized into five parts. Part I, "The Case Study Projects," consists of chapter 1 and covers the development of the projects and the experience upon which this book is based. Part II, "The General System Simulation Approach," consists of three chapters. The first, chapter 2, presents the conceptual framework of the general system simulation approach to improved decision making. The description focuses on a national decision structure concerned with agricultural sector development. The second, chapter 3, develops the public policy environment within which the agricultural sector operates and the policy choices available to the agricultural decision maker as influenced by the prevailing value system imposed by the socioeconomic, technical, and political environment. The third, chapter 4, covers a wide spectrum of model types and techniques, describes how they are used in decision analysis, and indicates their strengths and weaknesses.

Part III, "The Korean Agricultural Sector Models," consists of 9 chapters. The first, chapter 5, describes the process of sector model conceptualization in Korea. The next five, chapters 6 through 10, describe component models that constitute the Korean agricultural sector model system and give illustrations of their application for planning and policy analysis purposes. The five component models in the Korean agricultural sector model system are population, national economy, technology change, resource allocation and production, and demand-price-trade. The next, chapter 11, discusses data and parameter estimate requirements for the model and how they were obtained. The final two chapters in this part indicate the process by which the models can be used by decision makers (chapter 12) and a specific application of the models in long-term planning for land and water development (chapter 13).

Part IV, "The Korean Grain Subsector Models," illustrates the two subsector models built to focus specifically on short- and medium-term problems associated with the Korean government's grain management program. The first, chapter 14, discusses the grain management program model, developed for use as an on-line management tool for government decisions regarding the price, stock, storage, and trade of grain. The second, chapter 15, illustrates a small, static model used to analyze the consequences of grain pricing decisions on production, consumption, inflation, foreign exchange, and government grain management accounts.

Part V, "Technology Transfer," consists of four chapters that cover the problems, requirements, and process of integrating the use of quantitative analysis into the decision-making structure of developing countries. The first, chapter 16, discusses the requirements and prerequisites for institutionalization of the general system simulation approach into a national agricultural decision framework, and the second, chapter 17, indicates the amount and kind of training for indigenous personnel necessary to institutionalize the approach effectively. The third, chapter 18, illustrates the generalizations indicated in the previous two chapters through the experience in Korea, and the last, chapter 19, discusses the future directions necessary to further develop the approach in Korea, as well as to transfer the general approach to other developing (or developed) countries, subject matter areas, and problems.

PN-AAF-362

PART THREE

THE KOREAN AGRICULTURAL SECTOR MODELS

210 p.

5
AGRICULTURAL SECTOR MODEL CONCEPTUALIZATION: THE KOREAN EXAMPLE

Tom W. Carroll
George E. Rossmiller

In this chapter we present a brief description of the physical characteristics, the socioeconomic structure, and the institutional setting of the Korean agricultural sector. We then present an overview of (1) the perspective and values held by Korean decision makers with respect to the agricultural sector and its relation to the national economy; (2) the general set of problems that has determined the scope of the sector analysis and modeling effort reported earlier in the Korean Agricultural Sector Study (1972) [151] and updated in the following chapters; (3) the current broad design of the Korean Agricultural Sector Model System (KASM) in terms of its disaggregation levels, component models, and linkages; and (4) the broad policy areas addressable by the sector models.

THE KOREAN AGRICULTURAL SECTOR

The Republic of Korea is a peninsula in the temperate climate zone, bordered on the west by the Yellow Sea, on the east by the East Sea or Sea of Japan, and on the north at roughly the thirty-eighth parallel by the People's Democratic Republic of Korea. Seoul, the capital city in the northwestern part of the country, is at approximately the same latitude as Washington, D.C., and Lisbon, Portugal.

Of the 9.8 million hectares of land area, approximately 24 per cent, or 2.4 million hectares, is cultivated. About 70 per cent of the total land area is mountainous. Of the 2.4 million cultivated hectares, about half, or 1.2

million hectares, is paddyland suitable for production of the principal crop, rice. Approximately 80 per cent of the paddyland is irrigated.

In roughly the southern four provinces, a winter crop, primarily barley, is produced as a second crop on the paddyland. Upland crops are many and varied, including barley, wheat, and other grains and oil seeds; fruits, including the tree fruits — apples and pears and, on the southernmost island, oranges; vegetables, the most prevalent of which are Chinese cabbage. red peppers, garlic, and radishes; pulses including soy beans; both sweet and white potatoes; tobacco; mulberry, for sericulture; and ginseng. In winter, vegetables are grown in plastic greenhouses on paddyland, particularly near major cities.

Korea has experienced phenomenal economic growth since initiation of the First Five-Year Economic Development Plan in 1962. During the First Five-Year Plan period (1962–67), the average annual real growth rate for the total economy (including agriculture) was 7.8 per cent, and the rate for agriculture alone was 5.3 per cent. During the second plan period (1968–71), the average annual growth rate of the total economy was 10.5 per cent, and the agriculture rate was 2.5 per cent. In the third plan period the comparable figures are 9.4 per cent and 4.9 per cent, respectively. Thus, although the agricultural sector performance was quite respectable relative to agricultural sector growth rates in other developing, or for that matter developed, countries, it lagged behind the total national economic growth rate appreciably. Rapid farm-nonfarm migration during the first two plan periods softened the effect of this gap on a per capita basis but by the third plan period it was obvious to the government that further widening of the gap would be both economically and politically harmful. Thus, greater emphasis and investment were programmed for the agricultural sector in the Third Five-Year Plan.

The Korean farm unit averages about one hectare in size, with about one-third of all farm households having less than .5 hectare, one-third between .5 and 1 hectare, and one-third more than 1 hectare. Relatively few farms exceed 3 hectares, the legal limit on cultivated farm size. Human and draft animal power is the main source of energy, but mechanization, primarily in the form of 10- to 12-horsepower tillers and attachments, is increasing. Institutional credit and modern inputs are supplied mainly through the National Agricultural Cooperative Federation, a semiautonomous agency of the Ministry of Agriculture and Fisheries (MAF). This institution is also a major market channel, particularly for rice and barley, because it both markets on its own and handles government purchases for public use, stockpiling, and price support activities.

The total population of Korea in 1975 was about 34 million people — 45 per cent in the farm population and 55 per cent in the nonfarm population. The population growth rate is about 1.7 per cent per year, and because of farm to nonfarm migration, the farm population has declined absolutely since about 1967. This decline creates strong pressures to move away from subsistence production and toward the commercialization of farm households. It also suggests the need for increase in farm size and for labor-saving mechanization as the agricultural labor supply declines and as farm wages rise.

With rising real incomes, both farm and nonfarm, demand for food has increased rapidly. Per capita consumption of both rice and wheat has continued to increase, as has consumption of fruits, vegetables, meat, and dairy products. Scarce foreign exchange is required for the importation of rice, wheat, and feed grain. Grain imports have increased from about 700,000 metric tons in the mid-1960s to approximately 3 million metric tons in the mid-1970s.

Domestic production has also increased. Total crop production growth during the last decade has averaged 2.5 per cent annually, with rice production increasing 1.5 per cent annually. Total grain production has remained fairly constant at about 7.3 million metric tons in recent years because of a decline in barley and wheat hectarage. Fruit and vegetable production has increased at an annual rate of about 10 per cent, and livestock production has increased about 6 per cent per year in recent years.

To attain these increases in domestic agricultural production, both high-yield technologies have been developed and disseminated and projects have been implemented to expand the arable land base. The Agricultural Development Corporation, a semiautonomous agency of MAF, is responsible for the design and implementation of all agricultural land and water development activities in Korea. These activities include upland development, tideland reclamation, irrigation, drainage, and paddy rearrangement and consolidation. The Office of Rural Development, an agency of MAF, has responsibility for technical agricultural research and extension. Research and extension efforts have concentrated on increasing agricultural production, with primary emphasis on grains.

The continuing question facing Korean agricultural sector planners and policy decision makers is how to use the available resources to achieve an optimum growth rate and pattern in the agricultural sector as an integral part of, and contributor to, the development of the total economy. The accomplishment of this task required an increase in the investigative capacity dealing with the agricultural sector and interaction with agricultural administrators and executives responsible for agricultural sector development decision making. In 1971 the Michigan State University Agricultural Sector Analysis and Simulation Projects team was contracted to work with the National Agricultural Economic Research Institute in the Korean Ministry of Agriculture and Fisheries to help strengthen that investigative capacity on the basis of a comprehensive system simulation model of the Korean agricultural sector.

DECISION MAKERS' PERSPECTIVES ON THE AGRICULTURAL SECTOR

The beginning point in the Korean sector modeling and analysis activity was to determine the broad national values held by Korean decision makers with respect to Korean agricultural development. These values were not explicitly stated by Korean decision makers; nevertheless, "revealed preferences" could be found in the existing policies; in discussions with policy makers about their current problems, issues, and concerns; in preference patterns of consumption and production among farmers; and in the general political environment. The various national values were judged to cluster in four main categories:

1. Achieving improved food supplies, both quantitatively and qualitatively, preferably from domestic sources
2. Realizing a higher quality of life in rural Korea[1]
3. Enhancing and improving the contributions of the agricultural sector to the overall development of Korea
4. Improving administrative and political processes affecting Korean agricultural development

The structural and operational perspective of agricultural decision makers toward the agricultural sector and its relation to the rest of the Korean economy is presented in Figure 15. The two main exogenous factors from the "environment" that influence the performance of the system are the weather and the world prices for agricultural commodity imports and exports and for imported raw materials and manufactured products used as inputs to agriculture (e.g., fuel, fertilizer, machinery, etc.). The behavioral decision units within the system are divided into farm households and nonfarm households, with the associated respective economic activities of agricultural production and nonagricultural production and marketing. Operating at the interface between the agricultural and nonagricultural sectors are foreign trade activities, agricultural product marketing activities, and the agricultural input marketing activities.

Figure 15 also indicates the major flows of commodities, inputs, capital, labor, money, and price information among the sectors. The agricultural marketing system channels farm products directly to consumers or to the agricultural processing industries. The foreign trade sector exports Korean products to world markets and imports agricultural products to make up food deficits. Farm households are a net supplier of capital, labor,

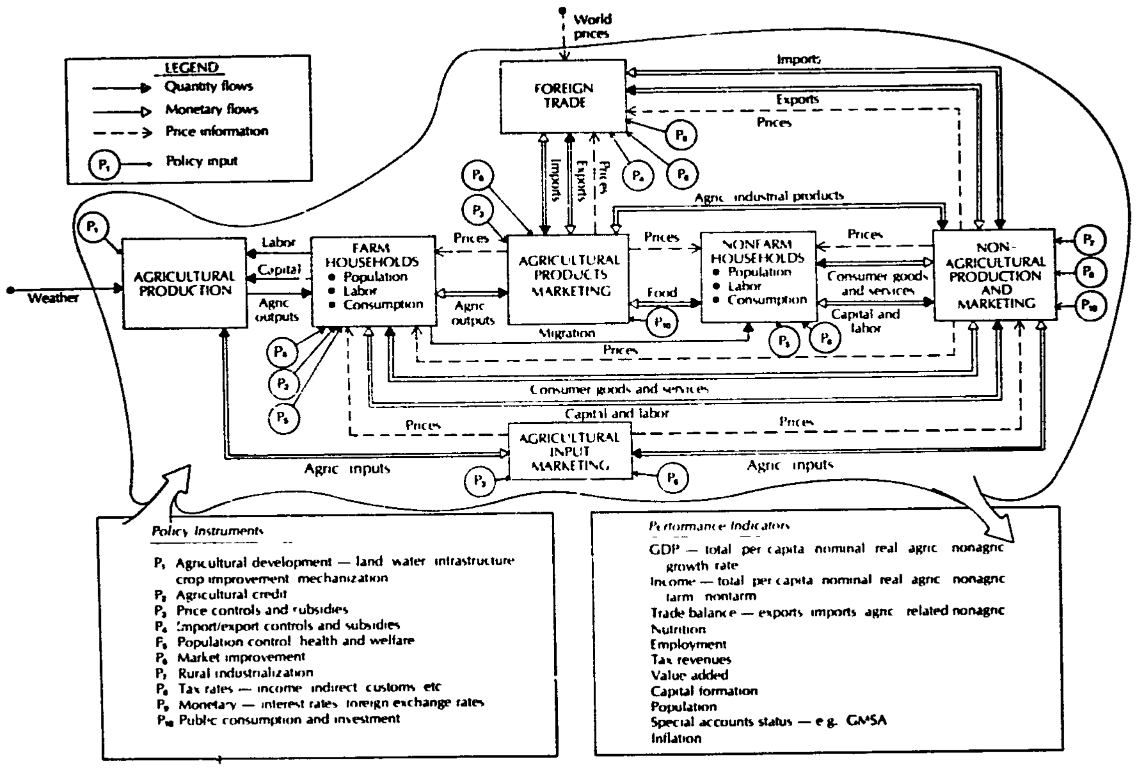


FIG. 15. An agricultural sector perspective of the Korean economy.

and migrants to the nonfarm sectors. The major inputs into the agricultural sector from the urban industrial sector include four basic products required to raise the level of agricultural technology: chemicals to control pests and diseases, fertilizer, farm machinery, and fuel.

The flows and activities outlined above are controlled by internal domestic prices, the influence of world prices, and the government's fiscal, monetary, regulatory, and investment policies. These government "policy instruments" include: (P_1) agricultural research and development programs and projects in land, water, infrastructure, crop improvement, mechanization; (P_2) agricultural credit; (P_3) price control and subsidies; (P_4) import/export controls and subsidies; (P_5) population control, health, and welfare; (P_6) market improvement; (P_7) rural industrialization; (P_8) tax rates (income, indirect, customs, etc.); (P_9) monetary policies (interest rates, foreign exchange rates); and (P_{10}) public consumption and investment in marketing facilities and nonagricultural production related to the agricultural sector.

"Performance indicators" are monitored by decision makers to see if the system is "on course" in reaching desired goals. At the national level these performance indicators include gross domestic product (total, per capita; nominal, real; agricultural, nonagricultural; growth rate); income (total, per capita; nominal, real; farm household, nonfarm household); trade balances; nutritional levels; employment levels; tax revenues; value added; capital formation; population levels and growth rates, including off-farm migration rates; status of special accounts (e.g., grain management and fertilizer); inflation rates; as well as other variables of interest.

The choice of strategies or policy sets and the goals themselves are determined by the political/administrative process. Formal planning exercises, which are carried out by policy-planning staffs, provide key inputs to the political/administrative decision-making process.

THE KOREAN AGRICULTURAL SECTOR AND ITS PROBLEM SET

At least three perspectives influenced the design of the Korean Agricultural Sector Models (KASM) from the time modeling activity started on a small scale in 1971: (1) a Korean perspective, which focused on substantive agricultural issues and problems identified earlier under the first three value sets related to improved food supplies, rural development, and agricultural sector contribution to national development; (2) a second Korean perspective, which was concerned with improving the administrative and political processes affecting agricultural development; and, finally, (3) Michigan State University's perspective, which was concerned with the "adapting and testing of agricultural simulation models to sector analysis," a generalized approach concerned not only with developing models for Korea but contributing to the development of a general "software library" of models and components, training packages, and institutional linkages to expedite application of the approach in other settings. Let us discuss these three perspectives and their influence on the evolving sector model design in more detail.

Korean Perspective: Agricultural Sector Development

The design of the sector model should reflect the concerns of agricultural decision makers regarding the significant, substantive problems of agricultural development during the next 10 to 15 years.

Improved Food Supply. The chief concern of Korean decision makers was that Korea domestically produce sufficient food to meet the effective demand from a growing population with rising per capita incomes in order to minimize expenditure of scarce foreign exchange on food and feed imports. To confront the set of problems implied by this concern, a sector model must be disaggregated to a level at which it can address the important questions related to the production and consumption of crop and livestock products (with the latter's associated consumption of feed grains).

It was estimated that Korea must expand food production by 50 per cent between 1970 and 1985; it was also estimated that there must be a 250-per-cent expansion in food processing and market services during this same period to handle the rapidly changing shift in the population balance between farm households and nonfarm households. The models were designed to estimate the magnitude of the shift and, thus, the demand for food processing and marketing services; but in their current state they do not actually model these subsectors in detail.

Rural Development. Korean decision makers were concerned with the effect of agricultural development policies on improving the quality of rural life, both absolutely and relative to urban life. Thus, decision makers' concerns with income and infrastructure questions had to be addressed by the sector models. All versions of the models included provisions for disaggregation of the population into farm household and nonfarm household. The current versions also provide for estimating income by farm household and nonfarm household. Because of the land reform in the late 1940s and the current three-hectare limit on ownership of paddyland, there was less concern with the variance of income within the farm sector than between the farm and nonfarm sectors. For this and other reasons discussed later, the distribution of income within the farm sector was not considered in the design of the sector models.

The models do not explicitly take into account nonagricultural aspects of rural development, such as health care, educational, or transportation and communication systems. The model design, however, allows KASM to provide input to decisions in these areas with respect to needs and capacity requirements by the agricultural sector and consequences on the sector of infrastructural change.

Agricultural Sector Contribution to National Development. Korean decision makers were naturally concerned with the contribution of the agricultural sector to total national development in ways that go beyond the production of food for the urban population. These contributions include (1) farm household labor for industrial and urban projects (particularly seasonal construction projects); (2) raw materials for industry (e.g., fibers, silk cocoons, medicinal ingredients, etc.); (3) earnings of foreign exchange through export of commodities like silk and import substitution of food and feed grain products; (4) land for nonagricultural uses; (5) savings, government tax revenues, and newly formed capital to develop both farm and nonfarm economies; (6) off-farm migrants who will both become permanent residents and contributors of labor in the urban, industrial sector and carry with them claims on capital in the farm sector. Although it is not possible for the sector models to handle endogenously all the flows and levels indicated above, the models should nevertheless, be designed to handle some variables as exogenous inputs (e.g., items 1, 4, and 6) and to output others as performance indicators (e.g., items 2, 3, and 5).

Korean Perspective: Improving Administrative Processes

From the beginning of the MSU project in Korea in 1971, Korean officials were interested in recommendations from project staff with respect to improving administrative structures within the Ministry of Agriculture and Fisheries. Some of these suggestions related to institutionalizing the human resources and administrative processes necessary to use and extend the analytical models. In designing the components of the sector models, the project staff kept in mind the purposes for which the models might be used. These considerations, in addition to the substantive concerns expressed by decision makers, influenced the design of the models.

Perhaps the most important result of this influence was that the models were designed to be flexible and adaptable. This means, first, that the emphasis was not to build one large comprehensive model that would attempt to answer all foreseeable questions. Rather, the emphasis was on building a set of *modular components*, each of which would not only address key questions in various subsectors[2] but which could also be linked together to assess consequences at the sector level for given policy sets. Second, these were designed to be *evolving* models that would change with the changing concerns of decision makers and with the ability of succeeding modelers to develop continuously better and more current models as assets of the nation's agricultural investigative capacity.

Another implied concern was that the sector model should help to improve the efficiency of the five-year planning process. That is, by harnessing the speed and accuracy of the computer and its ability to process large amounts of data and analyze many complex interrelationships, the process of preparing the five-year plans would be faster, require less manpower, and result in a higher-quality product. In terms of model design, this suggested that the models should have a planning horizon of at least five years and that a one-year increment for processing the models would be sufficient to capture much of the detail required in the five-year planning exercise. This also suggested that the models might be used to develop rolling five-year plans — plans that are updated once a year with the latest data and latest changes in the development strategy of the decision makers. The models could also be used to prepare a consistent set of agricultural accounts at the aggregate level. This dimension is useful for reporting the intermediate-range outlook.

Another concern was that the models be rich enough in detail that the effect of investment in the various subsectors on total agricultural production and other criteria could be compared and contrasted. This suggested that the models needed to include important subsectors: production, consumption, and trade, as well as agricultural-nonagricultural linkages. These are the substantive areas mentioned in the previous section. The point, however, is that the model had to be helpful in evaluating and comparing alternative programs and projects across the agricultural sector. The tendency in the past had been to make evaluations and decisions about programs and projects in isolation. It was hoped that the sector models would provide a tool for making comparisons.

Another implied consideration in model design was that the input policies and the output performance indicators should correspond reasonably well with the types of policies and indicators familiar to decision makers. In other words, there had to be correspondence between the way the model viewed the world and the way the decision makers viewed the world. As a result, an effort was made to design output tables that would be easily understandable and not too different in format from the types of tables that appeared in agricultural yearbooks and other publications. Also key variables were defined to correspond with previously accepted definitions.

Michigan State University's Perspective

In most cases the perspective of MSU and the U.S. Agency for International Development (U.S. AID) was consistent with the Korean perspective with respect to substantive content and administrative style. However, the MSU team had additional concerns that influenced the evolving model design. A primary concern was that the models, training, and institutional linkages developed in Korea should be useful in other contexts and other countries. Therefore, the objective of the work was not to develop specialized components useful only in the Korean situation. The main influence of this concern was probably at the level of programming and documentation. For example, instead of programming the model to handle exactly 12 crops, it was programmed to handle a number of crops specified by the user. This provided flexibility, not only in using the models in the Korean context but also in applying them in other countries.

MSU was also concerned with training students in the system simulation methodology. Therefore, the development of model components was undertaken as thesis work for master's or Ph.D. degrees. For example, the crop technology change model of KASM was developed as a dissertation research topic by a Korean Ph.D. candidate working at Michigan State University. This arrangement influenced the design of the first version of the component model and the timing of its integration into the total system of models.

SECTOR MODEL DESIGN

In keeping with the design principles outlined earlier (chap. 4), the Korean Agricultural Sector Model is comprised of modular components — that is, components that can either be run together to carry out a general sector analysis addressed to many of the questions outlined earlier, or be decoupled and run to perform specialized analyses related to particular subsectors, such as population, farm production, demand, etc. Therefore, KASM is not viewed as one model but as a system of models. A basic principle in the design of the KASM system was to allow considerable flexibility in using the models for exploring specific policy questions, as well as for general sector analysis and forward planning exercises. An overview of the basic design characteristics of KASM is presented below.

Time

By definition, sector simulation models involve time as a fundamental variable. Design decisions were required with respect to the planning horizon and the incremental time cycle. KASM was designed to operate on a planning horizon of 5 to 15 years, although it has been used for shorter-range analyses in the five-year planning exercises, as well as for longer-range planning up to 25 years. (The latter analyses concerned long-term population projections and a study of land and water development priorities.) This planning horizon and the general purposes for which the model was to be used influenced the choice of the basic time cycle and disaggregation levels included in the model. KASM operates on the basic time cycle of one year (in contrast to the Grain Management Program Model described in chapter 14, which operates on a time cycle of about two days). This is to say that the levels of endogenous stock variables at the end of one year are calculated as functions of the stock variables at the end of the previous year and of the rates of change during the past year. In other words, the shortest feedback loop in the model cannot be less than one year. Even though the resource allocation and production component allocates land and labor for the two main cropping seasons in Korea, the seasonal allocations still depend on the levels and rates for the previous year, not the previous season.

Disaggregation Levels

The following list summarizes the disaggregation levels for the important dimensions in the Korean Agricultural Sector Model.

Population Groups (2)
- Farm household
- Nonfarm household

Agricultural Subsectors (4)
- Annual crop
- Perennial crop
- Livestock
- Fishery (rudimentary)

Regions (1 or n)

National	or	Single-crop region Dougle-crop region Upland region	or . . .

Agricultural Commodities (19)

Rice	Potatoes	Milk
Barley	Tobacco	Pork
Wheat	Forage	Chicken
Other grains	Silk (mulberry)	Eggs
Fruits	Industrial Crops	Fish
Pulses	Beef	Residual
Vegetables		

Land Categories (4)

- Paddy
- Summer upland
- Winter upland (includes double-cropped paddy)
- Pasture

Factor Inputs (12)

- Land
- Labor
- Capital (farm implements, tillers, transplanters)
- Chemical fertilizer
- Organic fertilizer
- Pesticide
- Seed
- Fuel
- Oil
- Other Inputs

Population. The population is divided into the farm-household population and the nonfarm-household population. Each population group is further divided into single-year age-sex cohorts. It should be noted that the farm-household population is not further disaggregated by household income level, which would have been necessary if analysis of the effect of government policies on the distribution of income within the farm population were to have been analyzed. This was not done because Korean policy makers have been much more concerned with the average level of farm-household income vis-à-vis nonfarm-household income. Because there is a three-hectare limit on holdings of paddyland, the distribution of farm income is relatively unskewed compared with other less-developed countries.[3] To include the agricultural sector income distribution dimension would have added considerable complexity to the operating structure of the model, as well as greatly increased problems of parameter estimation. It will likely need to be done, however, at some point in the future if agricultural income distribution becomes a problem.

National vs. Regional Mode. Although the structure of the model was originally designed to operate regionally and included a three-region disaggregation of the country based on crop production patterns, the current version of the model operates at the national sector level. Operating the sector model in the national mode: (1) greatly reduces the execution time (approximately 4 minutes for a 15-year run in the national mode versus about 35 minutes in the three-region mode); (2) eliminates the extra work of aggregating time series data from the province level to the three ecological regions (single-crop paddy, double-crop paddy, upland) analyzed in the 1972 Korean Agricultural Sector Study; (3) produces output at the national level — the level of first concern for national decision makers; and (4) allows for testing of the overall design and structure of the sector model (particularly the recursive linear program component, which models resource allocation and production) without introducing the complexity of regionalization. However, because regional questions are important, later versions of the model should provide for "flexible regionalization" and should be linked to data systems that allow flexible aggregation of data inputs to allow analysis at levels of aggregation specified by the researcher.

Agricultural Commodities. The many different agricultural commodities that Korea produces[4] have been aggregated into the following 19 product groups: rice, barley, wheat, other grains, fruits, pulses, vegetables, potatoes, tobacco, forage, silk (mulberrv), industrial crops, beef, milk, pork, chicken, eggs, fish, and a residual category.

Factor Inputs. The following factor inputs are accounted for: land, labor, capital, chemical fertilizer, pesticides, seeds, fuel, oil, and other inputs. Four land categories are considered: paddy, summer upland, winter upland (including double-cropped paddy), and pasture. Capital inputs are further disaggregated into farm implements, tillers, and transplanters. Chemical fertilizer is not yet disaggregated into the three basic nutrients; disaggregation may be implemented in later versions.

Components and Linkages

The structure of the model is organized into five main analytical components, each of which, as noted earlier, is a model in its own right: (1) population (POPMIG), (2) national economy (NECON), (3) crop technology change (CHANGE), (4) farm resource allocation and production (RAP), and (5) demand/price/trade (DEMAND). The resource allocation and production component includes two subcomponents, farm resource allocation (FRESAL) and production accounting (PRDAC).

The components can be linked together to carry out a full-scale sector analysis or run separately and in combination for subsector analyses. Figure 16 indicates the linkages between the component models for a full-scale sector analysis.

Population and Migration Component (POPMIG). The population and migration component simulates farm- and nonfarm-population dynamics, including the process of off-farm migration. The effects of government policies regarding birth control and public health may be supplied indirectly to the model by means of exogenous projections of fertility and mortality. POPMIG outputs farm- and nonfarm-population levels, which are the main driving forces behind food demand, and agricultural labor supply, which influences rates of farm mechanization.

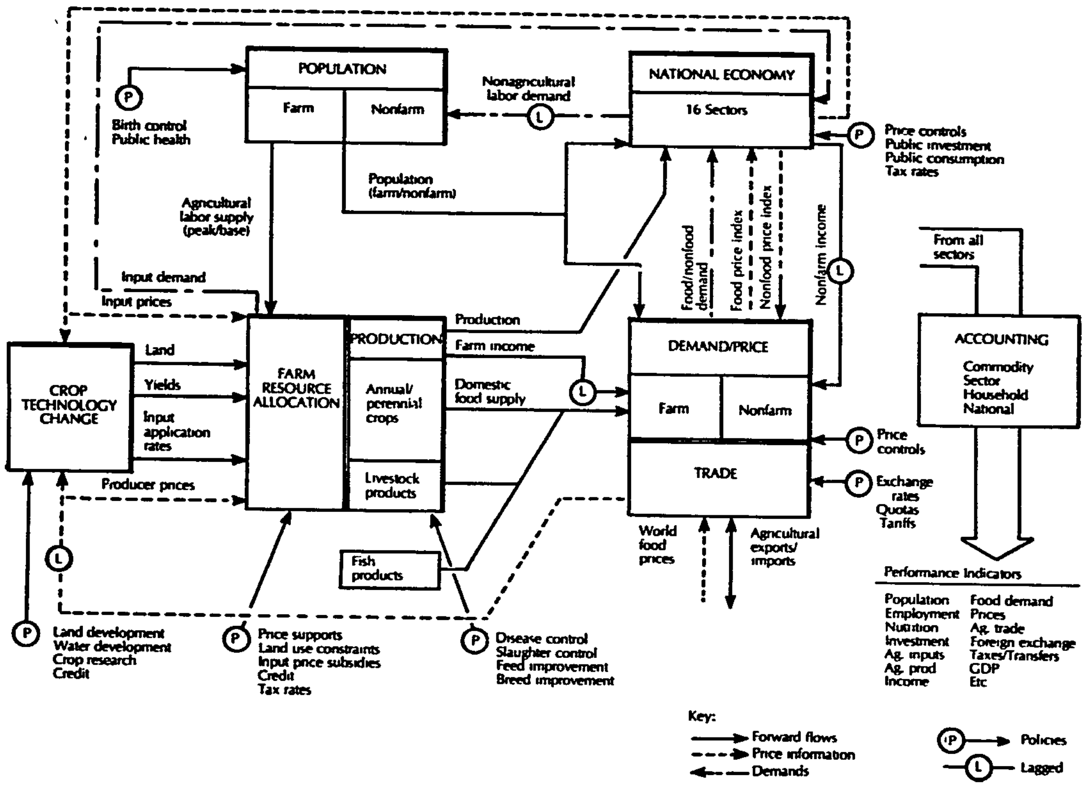
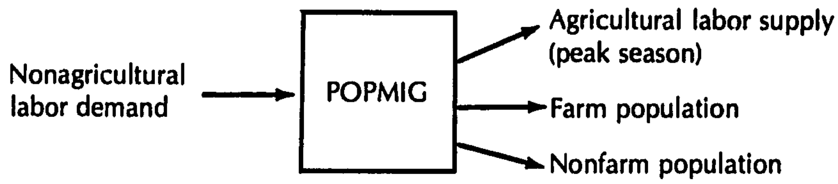


FIG. 16. Korean agricultural sector model: system linkage diagram.

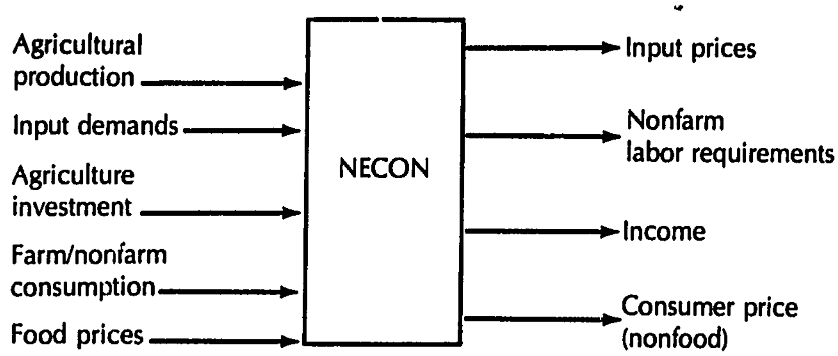
The main linkages of POPMIG with the other KASM components are:



National Economy Component (NECON). The national economy component, when linked with the rest of KASM, uses a 16-sector input-output model to simulate the important feedback linkages affecting the growth of the agricultural and nonagricultural sectors. For example, government programs to increase agricultural production can stimulate the demand for nonagricultural production by increasing the purchasing power of farm households. Increased nonagricultural production in turn increases nonfarm income and, hence, food demand, thus stimulating further growth in the agricultural sector. NECON's strongest ties are with DEMAND. Farm and nonfarm incomes, exponentially averaged, affect the income response in the consumption functions in DEMAND. Also, the aggregate price index helps determine expenditures on nonfood goods and services. Agricultural input price indexes are used in the production components (CHANGE and RAP). Intermediate input demands and agricultural output from RAP are used to modify the agricultural coefficients in NECON's input-output technology matrix. In addition, the demands from agriculture for investment goods are part of the final demand to the sectors in NECON which produce capital goods. NECON uses projections of farm and nonfarm populations in its consumption subcomponent and in computing per capita values of accounting variables. NECON's projections of labor requirements in the nonagricultural sectors are used by POPMIG as a driving force for off-farm migration.

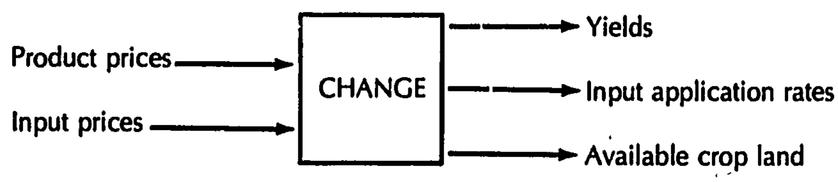
Since KASM is primarily concerned with agricultural sector analyses, the allowable policy inputs to NECON involve only nonstructural changes in the nonagricultural sectors. These policy inputs include projections of foreign exchange rates and farm and nonfarm income tax rates. Also, policy inputs for each of the 15 nonagricultural sectors include indirect tax rates, import tariffs, targets for import substitution levels, and projections of public investment and public consumption. Exogenous projections of dollar export volumes and world prices for each sector over time are also required by NECON.

The main linkages of NECON with other KASM components are:



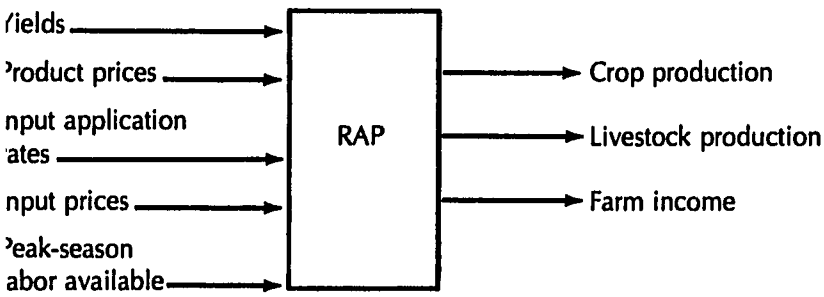
Crop Technology Change Component (CHANGE). The crop technology change component models the processes whereby the agricultural land/water resource base, variable input utilization, and, hence, productivities or yield levels of crops, change over time. The processes involve changes in the technology, institutions, and human resources associated with the agricultural resource base, particularly as generated through public policies, programs, and projects. CHANGE links public investment decisions with private decisions at the aggregated farm-firm level. The public policies that can be input into CHANGE concern (1) investments in land and water development programs (multi-purpose irrigation, consolidation, drainage, reclamation, conservation, pasture improvement); (2) investment in crop improvement research; (3) price policies (for inputs and products); and (4) credit policies. Crop yields, input utilization rates (fertilizer, chemicals, other materials, and labor), and total land by type (paddy, upland, potential double-crop land, and pasture land) are fed as inputs to the resource allocation and production component (RAP).

The main linkages of CHANGE with other KASM components are:



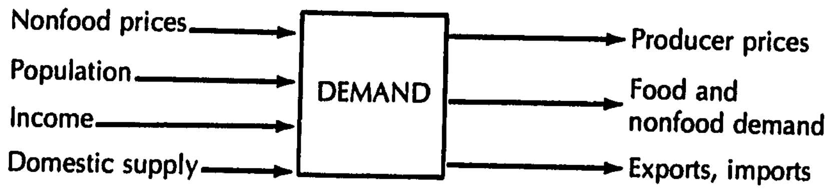
Farm Resource Allocation and Production Component (RAP). The resource allocation and production component uses a recursive linear programming model to simulate the annual resource allocation and production activities of the aggregated farm households as behavioral decision units. In addition to the inputs from CHANGE, other inputs include peak-season and base farm labor supply (from POPMIG), lagged producer prices (from DEMAND), and lagged input prices (from NECON). Policy inputs include commodity price supports, input price subsidies, credit constraints, interest rates, tax rates, and land use constraints. RAP outputs the domestic supply of 12 crop commodities (rice, barley, wheat, other grains, fruits, pulses, vegetables, potatoes, tobacco, forage, raw silk, and industrial crops) and five livestock commodities (beef, milk, pork, chicken, and eggs). The production of fish and the production of residual food are determined exogenously. Other outputs include farm income, feed grain imports, input demands, technology levels, shadow prices of fixed resources, capital stock, savings, and indebtedness.

The main linkages of RAP with other KASM components are:



Demand/Price/Trade Component (DEMAND). The demand/price/ rade component projects farm and nonfarm food consumption, producer ınd consumer prices, agricultural trade, and per capita nutritional levels, ın the basis of effective demand. DEMAND is a simultaneous equation component that solves for quantities demanded of 17 agricultural and 1 ıonagricultural commodities by farm and nonfarm households separately. Farm demands are satisfied first from domestic production under the ıssumption of predominately subsistence behavior. The residual of domesic production then becomes the domestic market supply to meet the ıonfarm-household demands. Surpluses are exported and deficits are atisfied through imports. Prices can be either part of the market clearing olution or set by assumption or defined as part of the solution. Farm ncome and domestic farm production are passed to DEMAND from RAP, ıonfarm income and nonagricultural prices from NECON, and both farm and nonfarm population from POPMIG. Lagged producer prices based on an assumed or a policy-established marketing margin are passed from DEMAND to CHANGE and RAP, and food and nonfood demand, exports, and imports to NECON.

The main linkages of DEMAND with other KASM components are:



Accounting Component. The accounting component is a set of print and plot subroutines that produce the tables and graphs summarizing the behavior of the various performance indicators over the planning horizon being considered. The output from a simulation run may be presented as a series of annual summary tables and/or summary time series plots.

POLICY ANALYSIS WITH THE SECTOR MODEL

The Korean Agricultural Sector Model is flexible enough in its present formulation to address a number of different policy questions.

Single-Run Analyses

The simplest mode of operation is to project for a 5-, 10-, or 25-year period the values of performance indicators of interest to decision makers under a set of policy assumptions that may have been determined independently of the model — either through the bureaucratic process or the political process. The value of the model in this case is that it can quickly produce a consistent set of results. For example, for the five-year plan projections the model might project the supply, demand, prices, imports, and exports of the main agricultural commodities; the agricultural input requirements; farm-household income and off-farm migration rates; and other, more detailed economic, demographic, and nutrition indicators. The model can also be used to update these projections as new data become available. It can also be useful in exploring the consequences of sudden "shocks" to the Korean economy, resulting, for example, from sharp increases in world grain prices for a several-year period or a sudden collapse in the world price of raw silk or sharp increases in fuel prices.

In both of these modes of use the focus of the decision maker is on the results from a single run. In the latter case, for example, the decision maker ght be asking, Can I really accept that large a deficit in the Grain ınagement Special Account under such a sharp increase in world price, en my current grain price policies, or must I change my policies?

mparative Policy Analysis

Most system investigators feel more comfortable in using the models for mparative policy analyses rather than in a single-run analysis. The ison is that they consider the models good enough to capture the major nds and operating characteristics of the system but recognize that under nditions of uncertainty the models cannot predict exactly what the ual values of the performance indicators will be 5, 10, and 25 years into future.

The usual mode of operation for this type of analysis is to specify a ase" run of the model in which current policies are assumed to continue o the future and/or no additional investment activity is specified (e.g., no ther investment in land and water development). Then, several different ernatives, short-term policies or longer-term strategies of development, run and their results compared with the results of the base run along a mber of different dimensions of interest to the decision maker.

The following are examples of comparative policy analysis that may be rried out using the current version of KASM.

Price Policy Analysis. Price policies are usually considered to be short-m control measures; however, pricing strategies likely will have long-rm consequences requiring careful analysis. Price policies for producers ıd those for consumers usually have conflicting objectives. Increased mestic production and high producer income may be the objectives of gher producer prices. Reduced food imports and foreign exchange costs ay be the objectives of import controls, higher consumer prices, and lministrative measures. Reducing inflation, controlling industrial wage sts, and maintaining the competitive position of export industries may be e goals of consumer price controls. In order to consider these policy uestions, a number of price and import policy options have been built into ASM.

Tax and Credit Policies. The government can control directly the tax ıtes levied on agricultural production and income. Indirect control can be chieved over credit available to the agricultural sector by guaranteeing ertain types of loans. KASM allows the policy planner to compose alterna-ve tax rates and credit policies, particularly to explore their effects on gricultural production and farm income.

Public Investment Policy Analysis. This type of analysis is usually arried out for a long-term investment program. One might analyze alter-ative public investments in biological research, extension, and land and water development on agricultural production and the demand for factor inputs (fertilizer, machinery, etc.) from the nonagricultural sector. Or, alternatively, one might analyze the impact of supply constraints and/or prices of factor inputs on agricultural production resulting from policies in the nonagricultural sector.

A later chapter (chap. 13) is a detailed case study of the use of KASM coupled with a polyperiod linear programming model in analyzing land and water development strategies, which include projects in irrigation, drainage, land consolidation, and reclamation of tidal land and forested slopeland.

Population Policies. The policy planner can use KASM to explore the effect of different assumptions regarding the rate of decline of fertility rates on the future population and the future labor supply. There are insufficient theories and data available to link expenditures on family planning programs directly with changes in fertility rates.

Through the migration mechanism, the planner can explore the effects of changes in the rate of off-farm migration on the future supply of agricultural labor and, thus, the impetus to increase farm mechanization. This may be done either directly by adjusting the off-farm migration rate exogenously or indirectly by adjusting employment generation policies in the nonagricultural sector. There is also provision for testing policies that encourage emigration, although it is doubtful whether these policies would have much effect, unless applied on a fairly large scale.

The following chapters describe the five major components of KASM in greater detail. As part of the discussion of each component, the types of problems that can be addressed from the problem set within the domain of the agricultural sector are indicated.

6
The Population Component of the Korean Agricultural Sector Model

Tom W. Carroll
John E. Sloboda

The purpose of the population and migration component (POPMIG) is to project the changes in the magnitude and structure of the population over a planning horizon of from 5 to 25 years. In order to explore structural changes of interest to agricultural development, the total population is divided into farm-household and nonfarm-household populations, with the population group of each sector being further divided into single-year age-sex cohorts. A standard cohort survival model is used to age and regenerate the two population groups. Off-farm migration is either specified exogenously or determined endogenously as a function of the gap between the demand for nonagricultural labor and the labor supplied by the internal growth of the nonfarm population. The main outputs of the population component are population numbers and labor supply. Nutritional needs in terms of daily protein and calorie requirements are also calculated. Figure 17 shows the linkage between the population component and other components in the Korean Agricultural Sector Model (KASM). The population component may also be run as an independent model, provided the necessary exogenous projections are specified.

The main inputs that can be indirectly influenced by policy decisions are age-specific fertility rates, age-sex-specific mortality rates, and age-sex-specific off-farm migration rates or, alternatively, nonagricultural labor demand from farm and nonfarm households. The next section of this chapter describes the seven operational steps carried out by POPMIG, and

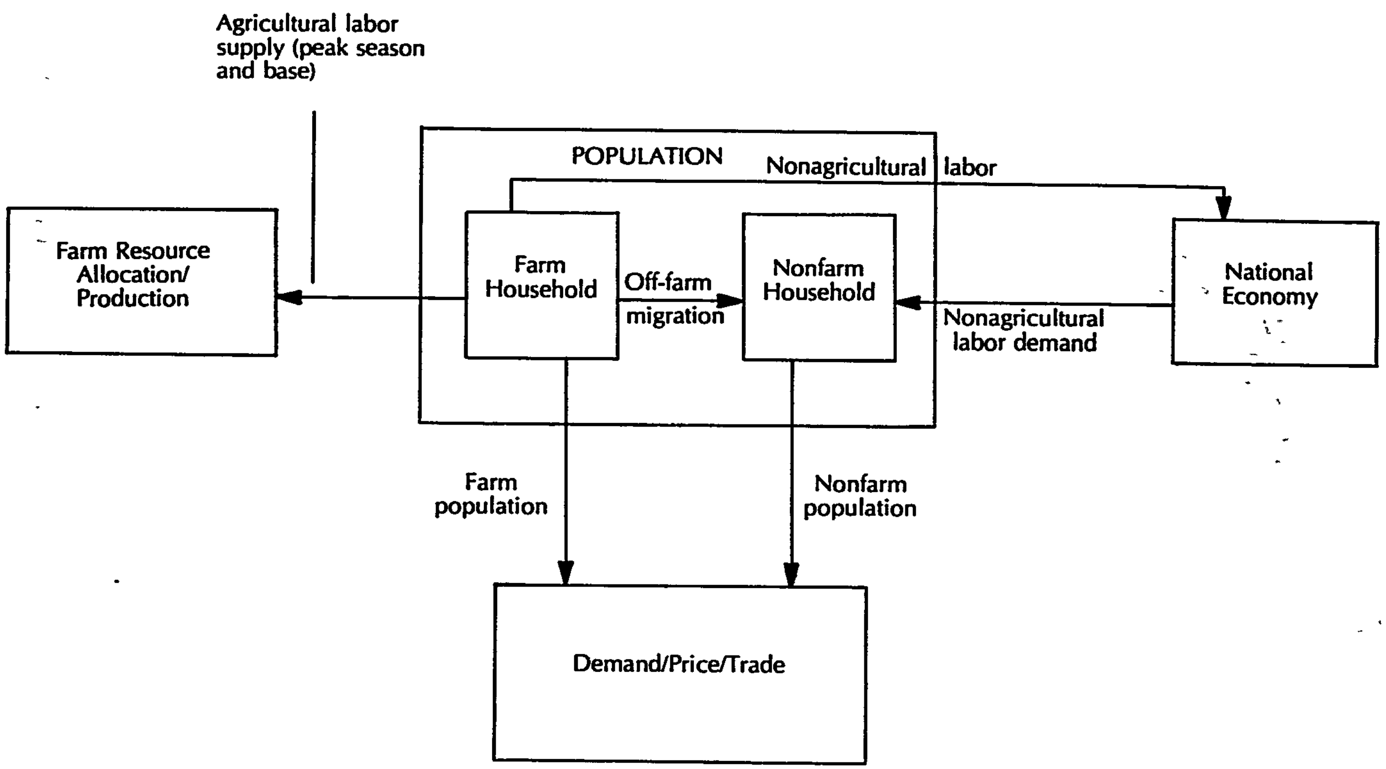


FIG. 17. Linkages between the population component and other components of the Korean agricultural sector model.

the following section discusses the data requirements for each step. The concluding section covers model testing.

COMPONENT STRUCTURE

In addition to initialization of the base-year population, the population component carries out six basic operations during its annual update cycle in the following sequence:

Aging of the population
Determination of single-age military service rates
Internal migration
Emigration
Fertility and infant mortality
Calculation of updated demographic, economic,
and nutritional variables

Initialization

The model requires estimates of the national and farm-household populations by five-year age-sex groups for ages 0–4 through 80–84 and 85+ for one or more alternative base years. These base years are usually selected to correspond to census years, when the best estimates of population levels are available.

The purpose of the initialization operation is to derive single-year age-sex cohorts for the farm-household and nonfarm-household populations from the five-year age-sex cohorts for the national and farm-household populations supplied to the model.

The initialization is accomplished in three steps. The normal census practice is to include all military service personnel in the nonfarm population. Because experience in estimating the off-farm migration rates (particularly in Korea, which has a large military force relative to population size) indicates that it is better not to confound off-farm migration with induction into military service, the first step involves redistributing military service personnel from the nonfarm population across both the farm and nonfarm populations. It is assumed, therefore, that the decision whether to leave the farm sector is made after completing military service. After adjusting the farm-household population to include members in the military, the farm-household population is subtracted from the total national population in order to obtain the nonfarm population by five-year age-sex groups. In the final step, the five-year age-sex cohorts for the farm and nonfarm populations are distributed into single-year age-sex groups for ages 0–84 using the Sprague method. The Sprague distribution function employs a set of coefficients by which each set of five-year cohorts is multiplied in order to separate it into single-year cohorts. The coefficients were determined by Thomas B. Sprague from a fifth-difference oscillatory interpolation formula. The Sprague method and other curve-fitting techniques may be found in [157]. The terminal group, age 85 years and over, is retained in aggregate form.

Aging and Mortality

The aging of each population stream is the first operation carried out in the annual population-update phase of the model. The standard cohort survival mechanism is used, whereby each single-year cohort from age 0 to age 83 is multiplied by an appropriate single-year survival ratio. The terminal-year age group is determined by multiplying the population 84 and over at the beginning of the cycle by an estimate of the proportion that will survive to reach age 85 and over one year later.

Determination of Military Service Rates

The purpose of determining military service rates is to adjust the age-specific military service rate profile. Because of the size of the military forces in a country like Korea, it is important that the effect of military service on patterns of migration and labor force participation be explicitly considered. Because of military service, a large proportion of the males from farm households in the ages 20 to 24 are recorded in the nonfarm household population at any given time. This has a very important effect on patterns of off-farm migration calculated directly from census data: it raises the apparent rate of such migration sharply in the age group 20–24 and lowers it, sometimes to negative values, in the age group 25–29, when many conscriptees are returning. Moreover, since the conscriptees are outside the civilian labor force, the size and age structure of the armed forces population also has an effect on the operation of the migration mechanism, which depends on the growth of nonagricultural employment.

Since using constant age-specific military service rates for all years of a simulation run would lead to unreasonable estimates of the size of military forces for some periods, the current approach is to specify exogenously the number of full-time, noncareer military personnel over the time period of a simulation run. Then, the age-specific military service rates are ratioed up or down by a uniform multiplier to generate new age-specific rates for the ages 19 through 35, which, when multiplied by and summed across the male age distribution, will yield the exogenously specified number of military personnel.

Migration

The off-farm migration mechanism operates in two modes. The first mode may be characterized as a policy parameter approach. In this mode the net overall rate of off-farm migration is specified exogenously over the time period of a simulation run. The second mode may be characterized as a labor supply-demand approach. In this approach the net overall rate of off-farm migration is determined endogenously in order to satisfy a nonagricultural labor demand-supply gap in the nonfarm sector.

The off-farm migration mechanism is an iterative, three-step operation involving both a net overall rate of off-farm migration and an age-specific net off-farm migration rate profile. In the first step the "nominal" net off-farm migration rate profile is applied to the population at risk to determine an *ex ante* estimate of net migration between the two sectors.

In the second step the ratio between the *ex ante* estimate of the appropriate criterion variable (depending on the mode) and the desired value of the criterion variable is calculated. In the policy parameter mode the criterion variable is the exogenously specified net overall rate of off-farm migration. In the labor supply-demand mode the criterion variable is the number of employed migrants, which is equivalent to the excess of demand for nonagricultural labor in the nonfarm sector over the *ex ante* supply. The excess of demand over supply is calculated as a function of (1) total nonagricultural labor demand (either exogenously specified or provided by the national economy component), (2) net off-farm labor supplied directly from the farm-household population to the nonagricultural sector (3) an exogenously specified urban unemployment rate, (4) age-sex-specific economic activity levels among the nonfarm civilian population, and (5) the civilian population distribution.

In the final step the ratio calculated above is used as a multiplier to adjust uniformly the nominal net off-farm migration rate profile up or down. To obtain age-sex-specific numbers of migrants, the farm population distribution is multiplied by this adjusted profile of migration rates.[1]

Having discussed the basic migration mechanisms, let us now turn to some of the assumptions regarding migration embedded in the model. The net migration profile referred to above is used to provide a pattern of relationships between the propensities to migrate among different age-sex cohorts. The operative assumption of the model is that although age-sex-specific net migration may vary over time, the relationships between the rates for any two age-sex groups remain constant. The relative differences between the net migration rates for the different age-sex groups reflected in the net migration profile are thought of as being determined by both individual and societal factors that influence occupational mobility among sectors and by the relationships between rates at different ages that arise through migration in family units.

Net migration can not be considered an appropriate dependent variable in analytical models that take a behavioral approach to interregional or interoccupational migration, since the number of "net migrants" and the net migration rate are simply artifacts of the cross-currents of real population movements. Nevertheless, it has been necessary to use a net migration approach in the current population model because of the lack of information on gross movements between the farm and nonfarm sectors. Although gross rural-urban migration statistics are available in Korea, research by Sloboda indicates that there are distinct differences between these patterns and the pattern of farm-nonfarm movement. Finally, it should be noted that the conceptual and theoretical difficulties involved in using net migration rates are less severe in the case of farm-nonfarm movement than in the case of rural-urban movement because of the relatively greater "efficiency"[2] of the former, particularly in the younger age cohorts that constitute the bulk of the migration stream.

It should be noted that in the labor supply-demand approach, migration is a direct function of the nonagricultural labor demand (lagged) and the unemployment rate. The former may be either exogenously specified or provided by the national economy component. The unemployment rate must be exogenously specified in the current model.

Emigration

Between 1955 and 1970 net annual emigration from Korea was insignificant, but in recent years the number of emigrants has increased sharply and the government has announced that it will promote overseas emigration by farmers and semiskilled workers while seeking to limit the outflow of skilled persons and capital. It remains to be seen to what extent persons with limited skills and resources will seek to emigrate and whether the potential recipient countries will be willing to accept them. Certainly past experience in Korea and elsewhere strongly suggests that voluntary emigrants will tend to be accepted if they are bearers of those human and financial resources that facilitate successful adaptation to a new social environment. Moreover, immigration policies are being reconsidered in the United States, Canada, and the countries of Latin America, countries expected to absorb most Korean emigrants; and it is expected that these countries will become more selective and restrictive in the future.

On the basis of these considerations, we have assumed that all emigrants will be drawn from the population of nonfarm households. No consistent data on past emigration trends could be obtained, and apparently no records are kept of the number of persons who successfully obtain immigrant status after going overseas for study or on business. Because no information was available on the age distribution of approved emigrants, let alone for *net* emigrants, it was simply assumed that one-half of the net emigrants would be between the ages of 20 and 39, one-fourth would be age 1–19, and the remaining one-fourth would be between the ages of 40 and 59. Within each of these broad age groupings, net emigrants were assumed to be distributed in proportion to the size of each single-year age-sex cohort.

Fertility and Infant Mortality

The determination of births, infant deaths, and the resulting population of age 0 in each sector at the end of the year is made subsequent to all adjustments for mortality, migration, and emigration. Separate patterns of age-specific fertility, varying over time, are assumed for the farm and nonfarm populations. Alternative assumptions concerning the changing pattern of fertility can be incorporated (albeit somewhat crudely) vis-à-vis a sectoral fertility adjustment coefficient within the model. Infant survival rates for the period from birth to the end of the update cycle are exogenously assumed to be the same in both sectors but to vary over time. The algorithm for calculating live births takes into account that the appropriate population at risk in bearing children is the number of fertile women who survive to the end of the year plus half of those who are estimated to have died during the year. The same ratio of male to female births is assumed for both farm and nonfarm women.

Calculation of Updated Demographic, Labor Force, and Nutritional Variables

Demographic Variables. The preceding operational steps in the annual update cycle yield an updated population distribution by sex and single-year age cohorts for each sector. These two population distributions include the active military service personnel in the sector of permanent residence and are used to calculate the crude birth rate, crude death rate, and crude growth rate for each sector and for the nation as a whole. An *ex post* net off-farm migration rate is also calculated. Next, new population distributions for the populations actually in residence for each sector are created by transferring farm-household military personnel to the nonfarm sector. The *de facto* residential population distributions provide a basis for comparing the projected population in each sector with actual census data. These populations are also used to calculate the agricultural labor force and to determine nutritional requirements by sector.

Labor Force Variables. The principal labor force variables calculated are the nonfarm labor force, nonfarm employment and unemployment, the base agricultural labor force, and the potential peak-season agricultural labor force. The nonfarm labor force and nonfarm employment are calculated on the basis of assumed nonfarm and migrant economic activity rates and exogenous projections of total nonagricultural employment, farm-household nonagricultural employment, and nonfarm unemployment rates.

The base agricultural labor force is determined in the model by applying assumed age-sex-specific rates of base agricultural labor force participation to the in-residence farm-household population distribution. Age-sex-specific data were available on the proportion of each five-year age-sex cohort reported as working "mainly in agriculture" and the proportion reported as working more than 90 days in agriculture. The larger of these two proportions was taken as the base agricultural labor force participation rate for that cohort.

Recent years have witnessed reports of agricultural labor shortages during the two peak seasons, which typically occur during June and October and span a total of roughly 60 days in any one area. Under the assumption that only the farm-household population currently in residence can provide labor to the agricultural sector, the model estimates the potential peak-season agricultural labor force on an annual basis by applying estimated age-sex-specific rates of participation in the peak-season labor force to the farm-household population distribution. To estimate the rate of participation in the peak-season labor force, it was assumed that those who worked fewer than 90 days in agriculture were drawn into the labor force when demand was greatest.

Both the base and peak agricultural labor force estimates are translated into adult male equivalents by using coefficients based on differences in work capacity by age and sex. Since the peak-season labor force participation rates indicate the proportion of each age-sex group available for the entirety of the 60 days encompassing the two peak periods, multiplying the peak-season manpower estimate by 60 yields the estimated supply of labor in adult-equivalent man-days available during the two busy seasons.

With respect to the effect on base agricultural manpower of changes in the ratio of nonagricultural to total farm-household labor, it is assumed that total manpower is reduced by the same proportion as the total labor force. No adjustment is made in peak-season labor force to account for changes in the proportion of the farm household working in the nonagricultural sectors. It is assumed that if a worker can procure nonagricultural work while continuing to live on the farm, then in most cases the work schedule can be adjusted to allow farm-household workers to work in agriculture during the peak periods.

Nutritional Requirements. This section is based on work reported in more detail in [164]. The population component calculates the projected calorie and protein requirements for the farm-household and nonfarm-household populations. These nutritional requirements provide a standard against which the effective demand (calculated in the demand component as a function of prices and income) may be compared. Average daily age-sex-specific calorie and protein requirements per kilogram of body weight are applied to projected changes in body weight to give these estimates of nutritional requirements. Additional calorie and protein requirements are also included to account for the additional needs associated with pregnancy and nursing. Both requirements are specified for the population of age 0, with the allowance for pregnancy covering the full 280 days of pregnancy and for nursing covering 10 months, a period chosen to represent average nursing practice. The nursing allowance is adjusted to provide for an efficiency factor of 80 percent in converting calories to milk.

For the adult population (age 20 and over), the calorie requirement is based on the level of work activity, which results in the farm population having a higher calorie requirement. The base of the model is the 1970 level of work activity. A change in the level of work activity may be incorporated by changing the calorie requirement per kilogram of body weight. A parallel adjustment is also included to provide for changes in average body weights of each age-sex cohort over time. In both cases, the model employs an estimate for 1970 and a projection for the year 2000 and then linearly interpolates for the intervening years.

DATA REQUIREMENTS

The data requirements for each of the operational steps are reviewed below.

Initialization

Estimates of the national and farm-household populations by five-year age-sex groups for the ages 0–4 through 80–84 and 85+, with foreigners excluded, have been prepared for three different base years: 1960, 1966, and 1970. Both the national and farm populations for 1960 and 1966 are based respectively on the 1960 and 1966 population censuses, with some upward adjustment for underenumeration. The national population for 1970 is based on the most recent revised Economic Planning Board adjustments to the 1970 Population Census; the farm population for 1970 is based on the 1970 Agricultural Census, with adjustments for underenumeration. Sources of data for initializing populations in 1960, 1966, and 1970 include [97, 98, 99, 108].

Mortality

The single-year survival ratios used in the aging operation are based on estimated single-year ℓ_a values interpolated from the Coale-Demeny model life tables. Different levels of the West family of Coale-Demeny model life tables were selected to represent the mortality regimes expected to hold for Korea at different times between 1960 and 2000. The selection of the Coale-Demeny levels was based on estimates of past and future Korean life expectancy taken from several sources, and the schedule of levels employed in the model reflects roughly the mean values of these estimates. To obtain the ℓ_a values for these fractional Coale-Demeny levels, single-year ℓ_a values were first estimated outside the model for the ages 0, 1, 2, 3, 4, 5, 10, 15, . . ., 65, 70, 75, 78, 80, 82, 83 for West levels 15 through 23 by linear interpolation. These derived ℓ_a values were also used to extrapolate ℓ_a values through age 100 at each benchmark level, providing the basis for calculating survival ratios for the terminal age group. Single-year survival ratios for ages other than those specified and for West levels other than the integer levels 15 through 23 are determined within the model through two-way linear interpolation.

The model allows for possible differences between farm and nonfarm mortality levels, but no specific data are available on differences between urban and rural mortality in Korea. However, there is no reason to believe that the differences are substantial, and it is likely that the differences between farm and nonfarm households are even narrower.

Military Service Rates

Although there are no available official statistics on the size and age distribution of Republic of Korea military personnel, these can be estimated indirectly with reasonable accuracy from census data. A comparison between the male five-year cohort populations indicated in Volume 4-1 of the *1970 Census of Population and Housing* [96] and the population in each cohort for which economic activity status is indicated reveals a discrepancy of 599,000 men between the ages of 15 and 54 for whom no economic activity status is reported. This number and the age distribution are very close to what one might expect for the population in active military service. These data formed the basis for calculating a nominal age-specific profile of the national average military service rate as required by the population component.

Migration

Since no statistics directly measuring off-farm migration are available for Korea and because of indications that the pattern of off-farm migration has differed significantly from the pattern of net rural-urban migration, off-farm migration was estimated from aggregate population data using the census-survival ratio approach (forward projection method). To produce an unbiased estimate of the net migration rate, this method requires that the population be closed to external migration, that interregional or intersectoral differences in age-specific mortality rates be negligible, and that the ratio of the regional (or sectoral) enumeration ratio to the national enumeration ratio be the same in both censuses for each age-sex group and the same for every age-sex group in the region or sector [62]. The first condition was approximately satisfied for Korea during the period 1960–70; and if the KASM/POPMIG adjusted census population were employed, it is believed that the remaining conditions would be sufficiently closely approximated to justify using this approach. Under the census-survival ratio method, as employed here, net off-farm migration and the net off-farm migration rate for each five-year age-sex group is calculated by estimating the survival ratio from time 1 to time 2 from the national population totals, multiplying this survival ratio by the farm population in the appropriate ages at time 1 to determine the expected farm population in the next age cohort at time 2 in the absence of net migration, and subtracting this expected population from the actual farm population in the same age cohorts at time 2 to estimate the extent of net migration. This estimate is a measure of migration among those who survive to the end of the period, and the net migration rate is thus appropriately calculated on the basis of the average farm population during the period, counting only those who survive to the end of the period (i.e., the average population at risk).

In order to avoid sharp fluctuations in the net migration rate profile for males between the ages of 20 and 30 caused by their entering and leaving military service, the census-survival ratio approach was applied to the populations and adjusted to include military personnel in the sector of origin. Because the age-sex selectivity of the military-adjusted net off-farm migration rates during 1966–70 was believed to be too sharply peaked among young adults to be representative of migration patterns occurring over the next several decades, it was decided to use the 1960–70 net migration rates as the profile pattern in the model.

Both the migration mechanism and the labor force calculations require estimates of the rates of the economically active population by age and sex, and the rate of urban nonfarm unemployment. Sources for these data in Korea included [95, 108].

Emigration

In the absence of more appropriate information, the assumptions concerning emigration currently employed in the model are based on data provided by the Ministry of Health and Social Affairs on the annual number of approved petitions for emigration between 1960 and 1973. These are gross figures, but the number of returning emigrants is probably more than offset by the degree to which these fall short of actual emigration. Assumptions about the projections of the historical data into the future must be supplied to the model.

Fertility and Infant Mortality

The basis for estimating and projecting age-specific fertility in Korea was the L. J. Cho estimates of age-specific fertility among the urban and rural populations during the period 1959–70 [31] and the average of the two estimates of the 1973 national age-specific fertility rates, based on the Continuous Demographic Survey and the 1974 Korean National Fertility Survey. The Cho estimates are based on census data, using the "own-children" method devised by Cho and Grabill. Next, a least-square regression of the general form

$$R_t(a) = A_a * e^{B_a t}$$

was fit to the age-specific fertility data for each age group and each sector. The estimation parameters A_a and B_a were then used to derive benchmark age-specific fertility rates for each sector at five-year intervals between 1960 and 1995. This approach to projecting fertility trends paralleled that used by the Korean Development Institute (KDI) to prepare national population projections for the Fourth Five-Year Economic Development Plan.

The exogenous projection of fertility outside the model and independent of other variables is theoretically unsatisfying, especially since fertility is the major variable in determining the future growth of the Korean population. However, the theoretical and empirical basis for estimating fertility as a function of other variables is relatively weak, and efforts in this area carried out elsewhere suggest that the estimates yielded by any of the current generation of causal fertility models would be likely to be further off the mark than a well-considered exogenous projection. The KDI "trend" projections of national fertility were deemed a reasonable basis for a "target" population projection for population policy during the Fourth Five-Year Plan because they remained fairly close to the fertility patterns experienced in Japan in terms of the relationship of age-specific fertility rates at each given level of total fertility. The KDI projections suggested a slower rate of decline in fertility than that which occurred in Japan: according to the KDI projections, total fertility[3] is forecast to decline from 3.85 in 1973 to around 2.1 in 1993 — roughly paralleling the drop that occurred in Japan between 1950 and 1958. A slower rate of overall decline in Korea was deemed realistic in light of differences in historical patterns of fertility, differences in the educational attainment levels of fertile women at the beginning of the period of rapid decline, differences in levels of female participation in the labor force, and differences in the proportion of fertile females in farm households.

Since age-specific fertility rates could only be estimated by five-year age groups, given the available data, single-year fertility rates were derived by entering the five-year age-sex fertility rates as single-year values at the average exact age of the cohort and interpolating other single-age fertility rates through the table function routines used in the model.

The same ratio of male to female births is assumed for both farm and nonfarm women. The sex ratio assumed in the model is 105.5 male births per 100 female births, somewhat higher than the average in countries with complete birth records, but consistent with Korean demographic patterns. Infant survival ratios were computed from the same Coale-Demeny model life tables used to estimate survival ratios at other ages and are handled in exactly the same manner in the model.

Labor Supply

In the farm-household sector the model requires age-sex-specific proportions of the farm-household population who participate in the base agricultural labor force (i.e., either work more than 90 days in agriculture or are working mainly in agriculture) and the peak-season labor force. These estimates were derived from [108]. To estimate the rate of participation in the peak-season labor force, it was assumed that those who worked less than full time in agriculture were drawn into the labor force when demand was greatest. Data were available on the number working in agriculture 0 to 30 days, 30 to 60 days, 60 to 90 days, and more than 90 days. Thus, it was assumed that those working fewer than 30 days in agriculture in 1970 worked an average of 15 days and that all of these labor days were contributed during the peak season. Those working 30 to 60 days were assumed to have contributed an average of 45 labor days, all during the peak season. Those working 60 or more days were assumed to have been available for the entirety of the peak season. Thus, a weighted, age-sex-specific, peak-season, labor-force participation rate was calculated.

Although it may be unrealistic to assume that those working fewer than 60 days in agriculture work only during the peak periods, the error introduced by this assumption is probably offset by the likelihood that as effective peak-season labor demand increases, the amount of labor contributed by non-full-time agricultural workers will also rise. This is already occurring, as is evident from the fact that the fraction of farm women of all ages and farm men over 60 who worked more than 60 days in agriculture was higher in the *1970 Agricultural Census* than in the agricultural census of a decade earlier. Both the base and peak agricultural labor force estimates are translated into adult male equivalents, using coefficients that reduce the human power output of young laborers under age 20, women between ages 20 and 55, and older laborers over age 55, relative to a reference male age of 20 to 55 [109].

In the nonfarm-household sector, the model makes estimates of the employed nonfarm population using age-sex-specific economic activity rates combined with the overall nonfarm unemployment rate. The source for these data has been [95]. Unpublished data from the 1970 census indicate that economic activity rates of civilian migrants differ significantly from those of the nonmigrant population; provision for this differential is built into the model.

The assumptions concerning the growth of total nonagricultural employment are based on preliminary projections made for the Fourth Five-Year Plan (1977–81) by economists at the Korean Development Institute.

Projections of nonagricultural employment in farm households may be provided to the model in two modes: (1) a projection of the absolute amount of employment, with the current projections being directly extrapolated from data for 1960 to 1970, assuming the historical annual growth rate of 4.5 per cent would continue; or (2) an exogenously projected number of off-farm workers per farm household, where the number of farm households is calculated as a proportion of the number of farm males, ages 25 to 59.

Nutrition

In order to calculate nutritional requirements, the model requires estimates of average daily age-sex-specific calorie (KCal) and protein requirements per kilogram of body weight and projected changes in age-sex-specific body weights.[4]

Policy Inputs

Of the various data input requirements summarized above, none, with the possible exception of the size of the military forces, is a policy instrument directly controllable by governmental decision makers. Some data inputs are clearly influenceable by governmental policies and programs. For example, the rate of decline in fertility rates is influenceable by effort expended on the family planning programs, and mortality rates are affected by expenditures on public health programs. Emigration rates are influenced by government targets and subsidies.

TESTING

The structure of the population component is not particularly complex or sophisticated. It is essentially an "accounting model" that keeps track of people by their attributional characteristics (age, sex, sector, employment, etc.). Thus, from a structural, operational point of view, not much work was required to test the logical consistency of the model structure. The main efforts went into using the model to check the consistency of the data inputs that were derived from a variety of sources and into making judicial adjustments where it seemed appropriate. For example, calibration runs, with the model using the initial arrays of farm and nonfarm age-specific fertility, gave evidence that, in general, actual farm-household fertility exceeded Cho's estimates for the rural sector as a whole, whereas nonfarm fertility was somewhat lower than that estimated for the urban sector. This discrepancy evidenced itself in sharp discontinuities between the size of the population aged 0 in 1961, 1967, and 1971 and the population aged 1 in the same years, as projected within the model from the KASM/POPMIG base populations. This gap was closed by adjusting the fertility adjustment coefficient to raise or lower total fertility (and age-specific fertility) by the required amount.

Current testing indicates that the projection of off-farm migration rates and, hence, of the farm/nonfarm split and of available agricultural labor supply is very sensitive, as might be expected, to assumptions about the growth of nonagricultural employment and the urban unemployment levels. Part of the problem has to do with definitions of employment, part-time employment, unemployment, etc., and the way that surveys collect these data. Experience with the population model indicates that more work is required in this area.

7
THE NATIONAL ECONOMY COMPONENT OF THE KOREAN AGRICULTURAL SECTOR MODEL

Michael H. Abkin

RATIONALE

The agricultural sector in Korea, as in any country, is an integral part of the national economy. Figure 18 highlights two major classes of interactions between the agriculture/farm and nonagriculture/nonfarm sectors of a nation's socioeconomy: demands for each other's products and competition for factor inputs. Classes of interactions not shown would include, among others, ecological and recreational influences (see chapter 3).

The implication in Figure 18 that farm is equivalent to agriculture and nonfarm is equivalent to nonagriculture is merely a simplification for demonstration purposes. Farm households frequently supplement their income through nonagricultural employment during slack seasons. In Korea, about 18 per cent of farm income derives from such sources, and a major rural welfare objective of the Korean government is to increase that nonagricultural contribution to about 26 per cent during the Fourth Five-Year Plan period, ending in 1981. Similarly, although to a lesser degree, nonfarm-household income may be augmented from agriculture through, for example, sharecropping and tenant farming.

On the demand side — the upper part of Figure 18 — are two of the strongest feedback loops between agriculture and nonagriculture (emphasized with thick arrows in the figure). Both of them are positive loops in that increases in agricultural production, say, lead to increases in nonagricultural production, which feed back to further stimulate agriculture. For

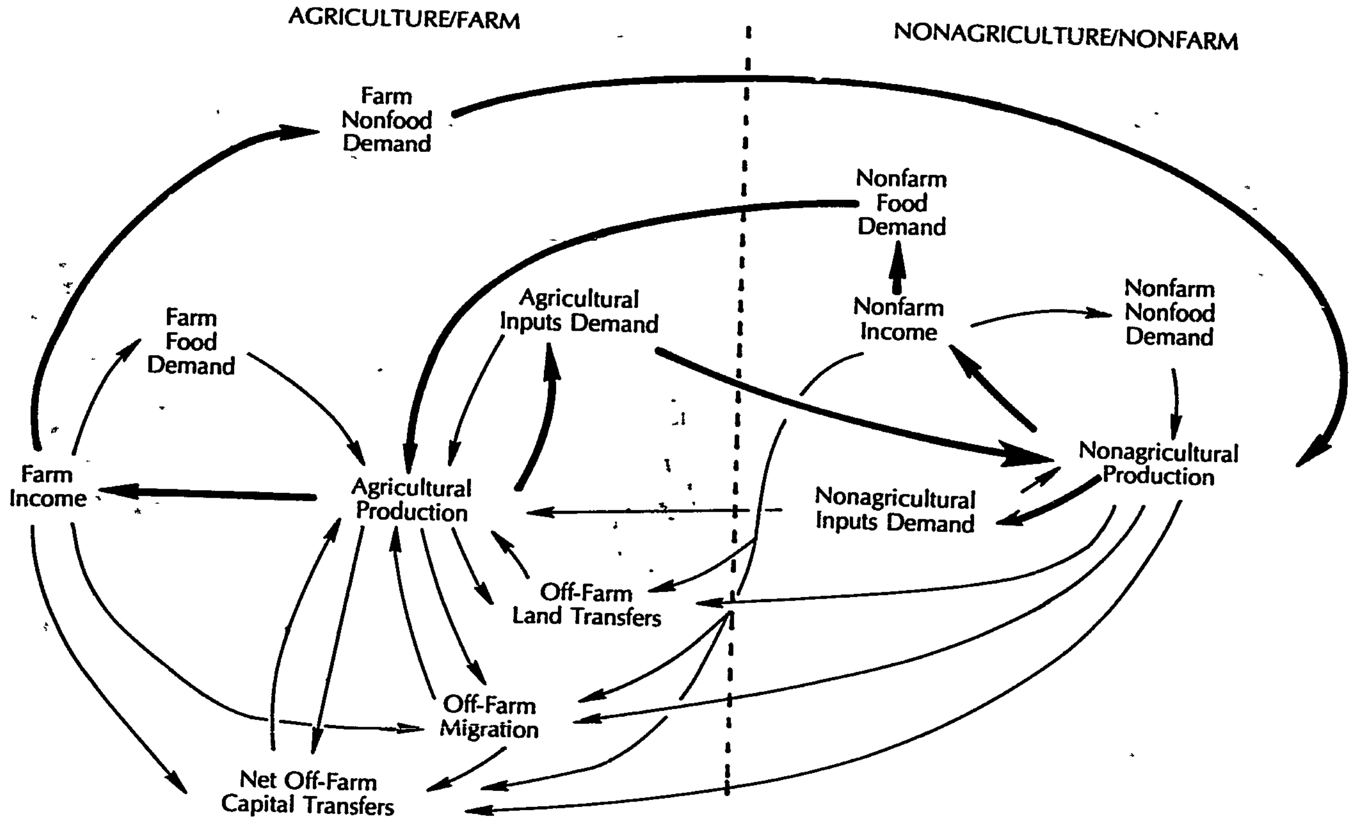


FIG. 18. Major linkages between the agriculture/farm and the nonagriculture/nonfarm sectors.

example, agricultural growth resulting from public investments in land and water development programs and crop improvement research and extension can increase farm income and, hence, farm consumers' demand for nonagricultural goods and services. In addition, demand for agricultural inputs will also rise to support the increased production levels. Both of these demands — for intermediate and capital inputs and for consumer goods and services — will stimulate increases in nonagricultural production to satisfy them.[1] Nonfarm income and, hence, demand for food will rise accordingly, providing a further stimulus for agricultural growth. Nonagricultural growth also positively affects agriculture by increasing demands for industrial raw materials.

The competition for factor inputs is diagrammed in the lower half of Figure 18, which emphasizes the feedback effects on agricultural production of losses of land, labor, and capital to nonagriculture. Land is transferred out of agriculture to satisfy the needs of an expanding industrial sector and to be used for residential construction for a growing population, demand for the latter being influenced by income, as indicated in Figure 18. In Korea, a land-poor country, arable land has been leaving agriculture at the rate of about 13,000 hectares per year. Without investments to increase the productivity of the remaining land or to reclaim new land, this can only have a negative impact on agriculture.

Agriculture also supplies the labor required by a growing nonagriculture. The net effect on agriculture of off-farm migration — which in Korea is occurring at a rate of about 3 per cent of the farm population per year — is mixed. If the necessary capital and technology are available to allow mechanization to replace the lost human labor without a loss in production, the increased productivity of the remaining labor will increase farm income, which will have a positive effect on agricultural production, as we saw above. In addition, migrants frequently return a portion of their nonagricultural income to agriculture in the form of capital transfers to their family members remaining on the farm. On the other hand, migrants who move simply to swell the ranks of the urban unemployed or underemployed will negatively affect nonfarm income and, hence, agricultural production through demand effects. Furthermore, migrants represent a drain on agricultural capital insofar as investment in their education was financed by agricultural production.

Finally, there is also competition between agriculture and nonagriculture for capital resources. Figure 18 refers to *net* capital transfers, implying that the flow goes in both directions, unlike the predominant pattern of land and labor transfers. As noted above, migration itself represents capital leaving agriculture and also generates a flow of nonagricultural capital back home to the farm. Capital also flows out of agriculture in the form of taxes and savings deposits. If the flow of subsidies, credits, and public investments and services back to agriculture exceeds this outflow, however, the net effect on the agriculture/farm sector can be positive.

The relevant question now concerns the relative strengths of these interactions and their implications for the design of agricultural sector analysis. One approach is to consider in the analysis only the effects of nonagricultural sector variables (e.g., nonfarm income) on agriculture, ignoring the feedback effects of agriculture on those variables. If the implicit assumption in this approach that any such feedback effects are negligible is realistic, then this approach is justified. On the other hand, if agriculture does significantly affect nonagriculture — and hence nonfarm income, for example — then the analysis must also consider the relevant causal linkages from agriculture to nonagriculture.

In Korea, the elasticity of nonagricultural production with respect to agricultural production in 1970 has been estimated to be .295. Conversely, the elasticity of agricultural production with respect to nonagricultural production was .854 in 1970.[2] For purposes of partial analysis of agricultural subsectors, such as demand projections or livestock production planning, it may be justifiable to treat as exogenous nonagricultural variables that influence the agricultural subsectors of concern. The above elasticities — as rough a measure as they are — imply, however, that comprehensive sector analyses of the consequences of agricultural policies and programs can treat nonagricultural variables as exogenous *only* at the risk of losing information important to public decision makers on the potential impacts on the nonagricultural economy of those policies and programs and the consequent secondary effects on agriculture itself. For example, the product of the above elasticities says that such secondary effects can be as much as 25 per cent of the primary effects.

This chapter describes the national economy component (NECON) of the Korean Agricultural Sector Model (KASM). The next two sections define NECON in terms of (1) its linkages with other KASM components and (2) its own internal structure. The following two sections discuss data requirements and model testing, and we conclude with a discussion of areas for further research and model development.

NECON BOUNDARIES

The boundaries of NECON are defined by its inputs and outputs. These are described in three categories — linkages with the rest of KASM, policy inputs, and other inputs and outputs — all shown in Figure 19.

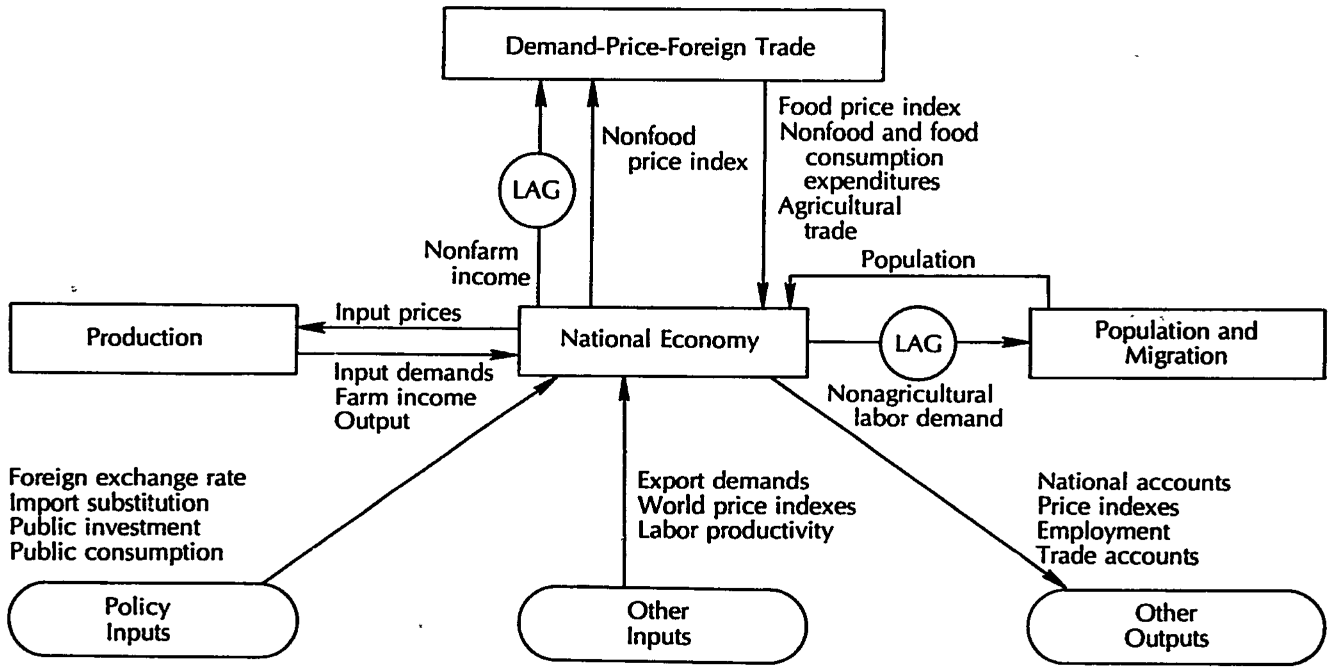


FIG. 19. Major linkages between the national economy component and the rest of the Korean agricultural sector model.

Linkages in KASM

The national economy component interacts with the production, de mand, and population components of KASM.[3] NECON's strongest ties are with DEMAND. Nonfarm income affects the income response and budget constraint in the consumption functions in DEMAND (see chapter 10). The aggregate price index of nonfood commodities generated by NECON helps determine expenditures on nonfood goods and services. These are fed back to NECON, where they are disaggregated by nonfood sector as a component of final demand. Finally, agricultural trade is used in NECON for the trade accounts and agricultural exports become part of final demand.

Agricultural input price indexes from NECON are used in the technology change component of KASM in the determination of yields and input application rates (chap. 8) and resource allocation decisions (chap. 9). In return, intermediate input demands and agricultural output are used by NECON to modify the coefficients in agriculture's column of the input-output technology matrix. In addition, agriculture's demands for investment goods are part of final demand for the capital goods-producing sectors of NECON.

Finally, NECON uses projections of farm and nonfarm populations in its consumption subcomponent and to compute per capita values of accounting variables. NECON's projections of labor requirements in the nonagricultural sectors are used by the KASM population component (POPMIG) as a driving force for farm-nonfarm migration.

Policy Inputs to NECON

Five policy instruments may be investigated with NECON. Since KASM is concerned with agricultural sector analysis, none of NECON's policy inputs involves structural change in the nonagricultural sectors.

Alternative levels of won-dollar foreign exchange rates may be projected over time as a policy input. NECON will show the effect of this policy on the won value of foreign trade accounts. Since export demands are projected for each sector in dollar terms, any effect that changes in the exchange rate might have on the dollar value of exports would have to be analyzed outside the model, if desired, and fed into NECON as new export demand projections. Similarly, on the import side, the effect of alternative exchange rates on domestic demand for intermediate inputs and consumer goods would be done off-line and result in changes in the import coefficients used in the model.

Various tax rates may also be specified by policy assumption in NECON. These include income tax rates for farm and nonfarm households separately, indirect tax rates for each sector, and import tariffs for each sector.

Government policies to promote import substitution may also be tested. Import-substitution coefficients are computed for investment goods, consumer goods, and intermediate inputs. These computations reflect exogenous assumptions about the achievement of target import-substitution levels, without regard to *how* these levels might be achieved. Thus, NECON can address such questions as, What would be the consequences of achieving target import-substitution levels?, but not how the government might achieve them. Finally, public investment in each sector and public consumption of each sector's output are projected as policy inputs to NECON.

Other Inputs and Outputs

As mentioned above, the dollar value of exports for each sector is projected over time outside the model for use by NECON. These exogenous projections may be based on trade analyses of Korea's potentials in world markets or merely on assumed policy targets. World and domestic producer price indexes for each sector are similarly projected.

Changes in labor productivity in each sector are computed by NECON on the basis of exogenous assumptions of ultimate values of labor productivity and of the speed with which those targets will be reached. These productivity projections affect the nonagricultural labor requirements that feed back to KASM's population component to determine off-farm migration.

In addition to outputs of NECON that go to other KASM components, NECON computes other performance criteria for use in evaluating model performance. Some of these include national accounts (total and per capita GDP and income, profits, wages, value added), sector-specific market price indexes, employment in each sector, and foreign trade accounts.

STRUCTURE OF *NECON*

The national economy component is basically a recursive input-output model of the Korean economy in which the recursion takes place via the linkages (discussed above) with the rest of KASM. In general, farm income, agricultural production, part of the final demand vector which drives the input-output (IO) production model, and part of the IO technology matrix are determined in the agricultural sector model. Likewise, nonfarm income and agricultural input prices, important drivers of food consumption and agricultural production, respectively, are determined in NECON.

NECON disaggregates the economy into 16 sectors. The behavior of the first sector, agriculture, is an aggregation of the behavior of the agricultural sector as projected in detail by KASM. Table 1 relates NECON's 16 sectors to the Bank of Korea's 56-sector classification [16]. This 16-sector classification emphasizes the major agricultural intermediate input and investment good industries: chemical fertilizers, machinery, fuels, and construction. Pesticides are included in the "other chemicals" sector.

The internal structure of NECON is diagrammed in Figure 20. Exogenous inputs and outputs of each of the six subcomponents shown in Figure 20 are classified according to whether they represent (1) linkages with the rest of the agricultural sector model (KASM), (2) policy inputs, or (3) other exogenous inputs and performance criteria outputs. Brief descriptions of each of the six components follow.

Consumption

The consumption subcomponent computes private per capita and total demand for domestic and imported consumer goods.

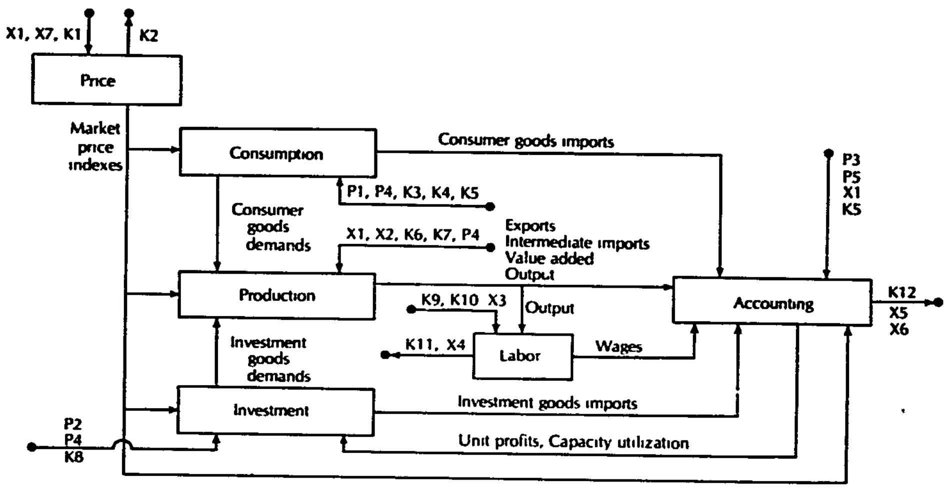
The food consumption component of KASM (chap. 10) projects farm and nonfarm demand for 19 agricultural commodities and one aggregate nonagricultural commodity. In order to maintain consistency under sequential (rather than simultaneous) solution of the two consumption components

TABLE 1
Korean Sectoral Classifications

Korean Agricultural Sector Study 16 Sectors		Bank of Korea 56 Sectors
1. Agriculture	AG	1. Rice, barley, and wheat (polished) 2. Vegetables, fruits, and other grains 3. Industrial crops 4. Livestock breeding and sericulture 6. Fishery products
2. Forestry	FOR	5. Forestry products
3. Mining	MIN	7. Coal 8. Metallic ores 9. Nonmetallic minerals
4. Chemical fertilizers	CHF	26. Chemical fertilizers
5. Other chemicals	OCH	24. Inorganic chemicals 25. Organic chemicals 27. Drugs and cosmetics 28. Other chemical products
6. Machinery	MA	37. Nonelectrical machinery 38. Electrical machinery 39. Transportation equipment

TABLE 1 (continued)

Korean Agricultural Sector Study 16 Sectors		Bank of Korea 56 Sectors
7. Fuels	FU	29. Petroleum refining and related products
		30. Coal products
8. Other heavy manufacturing	OHM	20. Lumber and plywood
		21. Wood products and furniture
		22. Paper and paper products
		31. Rubber products
		32. Nonmetallic mineral products
		33. Iron and steel
		34. Primary iron and steel products
		35. Nonferrous metal ingot and primary products
		36. Fabricated metal products
9. Food processing	FP	10. Slaughtering, dairy products, and fruit processing
		11. Canning and processing of sea foods
		12. Grain polishing and milling
		13. Other food preparations
		14. Beverages
		15. Tobacco
0. Textiles	TX	16. Fiber spinning
		17. Textile fabrics
		18. Apparel and fabricated textile products
1. Other light manufacturing	OLM	19. Leather and leather products
		23. Printing and publishing
		40. Measuring, medical, and optical instruments
		41. Miscellaneous manufacturing
2. Trade	TRD	50. Wholesale and retail trade
3. Transportation and storage	TS	49. Transportation and warehousing
4. Construction	CON	42 New buildings and maintenance
		43. Public utilities and other construction
5. Utilities	UT	44. Electric utilities
		45. Water services
		48. Communications
6. Other services	OS	46. Financing and insurance
		47. Real estate
		51. Government services
		52. Social services
		53. Other services
		54. Office supplies
		55. Business consumption
		56. Unclassifiable



KEY TO INPUTS/OUTPUTS

KASM Inputs/Outputs

K1—Food prices
K2—Agric. input prices
K3—Food consumption
K4—Total nonfood consump. expenditures
K5—Population
K6—Agric. exports
K7—Agric input demands
K8—Agric investment
K9—Agric employment
K10—Agric wages
K11—Nonagric labor requirements
K12—Disposable income

Policy Inputs

P1—Public consumption
P2—Public investment
P3—Foreign exchange rate
P4—Import substitution
P5—Tax rates

Other Inputs/Outputs

X1—World price indexes
X2—Export demands
X3—Labor productivity
X4—Employment
X5—National income accounts
X6—Trade accounts
X7—Domestic producer price indexes

FIG. 20. Internal structure of the national economy component.

(KASM's and NECON's), all interaction between food and nonfood demand (i.e., via cross elasticities) takes place in the food demand model of KASM. In NECON, then, the aggregate nonfood consumption expenditure computed in KASM for farm and nonfarm consumers is disaggregated among the 14 nonfood sectors.

For each class of consumers, farm and nonfarm, the private consumption function is of the same form as the food demand model (chap. 10).

$$\mathbf{C}(t) = \mathbf{C}_0[f\{\mathbf{P}(t), X(t), G(t)\}]^{S(t)} \tag{1}$$

where **C** is a vector of per capita consumption in each nonfood sector, **P** is a vector of price indexes, X is total per capita nonfood consumption expenditures, G is per capita gross domestic product, and S is an elasticity expansion parameter computed by the model to force the budget constraint (see below). Per capita gross domestic product is included as a measure of national development and modernization, which was found to be significant in explaining consumption levels in certain sectors; namely, transportation, utilities (which includes communications), and other services.

The function f in equation (1) is of Cobb-Douglas form, where the exponents of **P**, X, and G are elasticities — hence, the term "elasticity expansion parameter" for S. S is a number, nominally of unit value, which is computed to ensure the budget constraint, where the constraint is total nonfood expenditures computed in the food demand component of KASM. That is,

$$\mathbf{P}^T\mathbf{C} = X \tag{2}$$

must hold at each point in time.

Total consumption demand for each sector is computed by multiplying per capita demand by population and adding an exogenous projection of public consumption. Consumption is disaggregated into demands for domestically produced and imported consumer goods using import coefficients that vary over time according to import-substitution policies.

Investment

The investment component computes net and gross investment, demands for domestic investment goods, and imports of investment goods. The proportional rate of change of private net investment in nonagricultural sectors (except residential construction, which is a separate function of income and population) is postulated to be a function of the proportional rates of change of profits per unit output and of capacity utilization. In Cobb-Douglas form,

$$I_i(t) = I_{i0}R_i(t)^{\alpha_i}U_i(t)^{\beta_i} \tag{3}$$

for each nonagricultural sector i. Investments in agriculture are computed in KASM. In equation (3), I is private investment, R is profits per unit output, U is a measure of capacity utilization, and α and β are elasticities.

Equation (3) postulates that changes in private net investment are driven by changes in profits per unit output and by changes in capacity utilization (measured indirectly as discussed below). Modeling, in this way, the causal basis of net investment is an attempt to avoid some of the problems associated with modeling current investment (as is common practice [70, 89]) as a function of future changes in output; i.e., what investment must be at time t to enable a change in output at time $t+\tau$, where τ is a gestation lag. One theoretical and practical problem with this approach is the use of changes in actual output rather than capacity output.

There is general agreement that capacity output would be the proper concept to use, but difficulties in defining and measuring it reliably [91] have led to the use of actual output in its place. In NECON, however, we have tried to measure proportional changes in capacity utilization indirectly as proportional changes in output per unit capital stock (instead of per unit capacity output). This is not an unreasonable measure if the ratio of capacity output to capital stock can be assumed to be constant. Although equation (3) may be adequate for NECON's purposes, the relationship of investment to capacity utilization is the subject of much needed advances in investment/disinvestment/user cost theory to take explicit account of the rate of use of capital services [17].

After computing private net investment, NECON adds public investment and replacement investment (assumed equal to depreciation) to private net investment to calculate gross investment. Investment in each sector is then translated into demands for investment goods from each sector. Using import coefficients that depend on import-substitution policies, investment demands are split into demands for domestically produced and imported investment goods. Finally, in the computation of capacity utilization, capital stock in each sector is the integral over time of net investments, allowing for investment gestation lags.

Production

Based on final domestic demand, the production subcomponent computes output and unit value added for each sector. Final domestic demand for each sector's output is the sum of domestic consumption, investment good demand, and exogenous projections of export demand. As a simplification, inventory changes do not appear in the final demand vector. In 1970, only about 1.5 per cent of total output went to inventory changes. This assumption can be changed, if necessary, without too much difficulty, since inventory coefficients do exist [63, 89].

Constraints on production — particularly constraints on capacity and on skilled labor — are not directly considered in the model. The primary purpose of NECON — to link agriculture with nonagriculture, rather than to project and analyze Korean industrial development — does not justify the increased complexity and costs of a constrained model; e.g., some kind of programming algorithm for the production component, a population component disaggregated by skill level, and direct measurement of capacity. However, NECON does address the capacity problem indirectly by making private net investment a function of capacity utilization.

For its purposes, NECON assumes the input-output coefficients for the 15 nonagricultural sectors (at constant relative prices) will not change over the time horizon of the model. Although this is certainly an unrealistic assumption, it is beyond the scope of NECON to project changes in the technological interdependence of Korean industry. If such projections are done by other researchers and made available, they can be incorporated into the model. In the meantime, results of *agricultural* analyses should be interpreted in light of this assumption that nonagricultural technology will not change or will change only in such a way as to leave the input-output coefficients unchanged. The fairly high degree of aggregation (16 sectors) will tend to reduce the errors introduced by this assumption relative to what they would be in a more disaggregated model. In addition, NECON does consider the effects of changes in relative prices and of import-substitution policies.

The input-output coefficients for agriculture, on the other hand, will change in the model on the basis of KASM projections of input demands and agricultural output. For the current version of KASM, coefficients are changed over time only for chemical fertilizers, other chemicals, fuels, other heavy manufacturing, and other light manufacturing. The 1970 Bank of Korea coefficients are maintained for the other agricultural inputs and for the coefficients of the other sectors.

In matrix notation, output is

$$\mathbf{OUT}(t) = [\mathbf{I}-\mathbf{AD}(t)]^{-1}\,\mathbf{FDD}(t) \qquad (4)$$

where **OUT** is the vector of sector outputs, **I** is the identity matrix, **FDD** is the final domestic demand vector, and **AD** is the matrix of domestic intermediate input requirements per unit output. **AD** is computed to account for import requirements and relative price changes. Finally, the production subcomponent computes value added per unit output and imports of intermediate inputs, the latter based on import coefficients resulting from import-substitution policies.

Labor

The labor subcomponent computes labor requirements and wages by sector and for nonagriculture in the aggregate. Agricultural employment and wages are determined in the agricultural production component of KASM.

Labor productivity in each sector is assumed to increase asymptotically to an upper limit. Actually, NECON models the converse of this; i.e., labor requirements per unit output decrease asymptotically to a lower limit (Fig. 21). For each sector i,

$$\frac{dL_i(t)}{dt} = \frac{1}{\eta}\,[FL_i - L_i(t)] \tag{5}$$

where L is employment per unit output, FL is the limiting value of L, and τ is a time constant that determines the speed with which L approaches FL.

Wages (including salaries, bonuses, etc.) are projected, assuming real wages per unit output tend to be constant. Again, it would be easy to make other assumptions; however, it is beyond the scope of NECON to project nonagricultural wages endogenously as a function of other economic variables in the model. This would require a much more complex employment model.

Price and Accounting

The price component generates market price indexes for nonagricultural sectors based on exogenous projections of producer price indexes, world price indexes, and trade and transportation margins. Price indexes of the agricultural and food processing sectors depend on food prices determined in the demand component of KASM (chap. 10).

Whereas domestic market price indexes depend on producer price indexes and trade and transportation margins, the consumers' market price indexes and the investors' price indexes are weighted averages of the

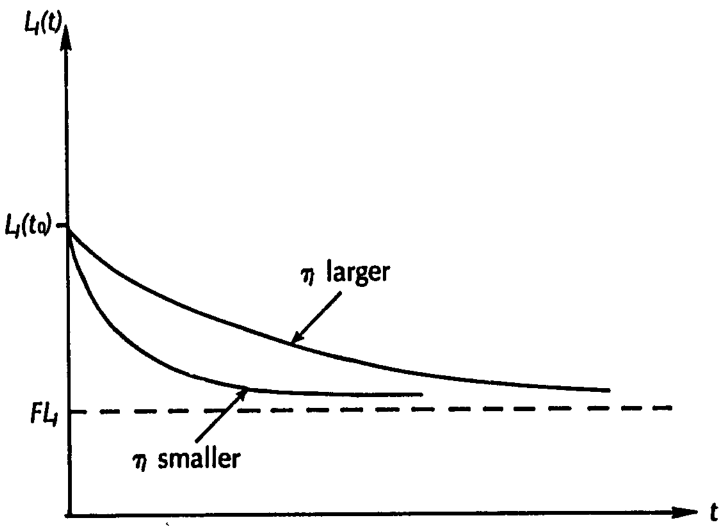


FIG. 21. Projection of unit labor requirements.

domestic market price indexes and the world price indexes, where the weights used are the consumer goods and investment goods import coefficients, respectively. In addition, the price component computes agricultural input price indexes needed by the production components of KASM and the aggregate nonfood price index used in the demand component of KASM.

The accounting component computes national accounts and other economic variables needed in other components of NECON, in KASM, and as measures of system performance. These include total and sector-specific value added and its components, total and per capita nonfarm income, agricultural and nonagricultural income, unit profits for the investment functions, trade balance, tax revenues, and gross domestic product.

DATA REQUIREMENTS

The data needs of any model fall into three categories: initial conditions, constant parameters, and policy parameters. Also required to run a model are projections of the exogenous input variables. The categories are not distinct in that policy parameters overlap the other categories; i.e., some are initial conditions, others are constant coefficients, and still others may be exogenous projections over time. Data needs of the national economy model (NECON) will be discussed by subcomponent, in the same order as in the last two sections.

Inputs to NECON

There are three sources of inputs to NECON: KASM, policy assumptions, and exogenous projections. These have been discussed earlier in this chapter so they will not be repeated here. It is sufficient to point out that if NECON is used independently of one or more KASM components from which it requires inputs, those inputs have to be supplied exogenously.

Consumption

Constant parameter data requirements of the consumption subcomponent include — for farm and nonfarm consumers and for 11 of the 16 sectors[4] — own- and cross-price elasticities, expenditure elasticities, and elasticities with respect to GDP. These elasticities have been estimated for nonfarm consumers on the basis of time series compiled from urban-household surveys [101] and price surveys [102]. Estimation for farm households has been difficult since farm-household surveys [107], until just recently, have not collected consumption data at a level disaggregated enough to permit reaggregation under NECON sector definitions. For the time being, therefore, NECON uses nonfarm elasticities for both consumer groups. Additional constant parameters required for the consumption subcomponent are trade and transportation margins for consumer goods. These are derived from Bank of Korea (BOK) input-output data [16].

Initial conditions required are (1) per capita consumption expenditures for farm and nonfarm consumers in each of the 11 nonfood sectors and (2) the budget constraint elasticity expansion parameter. The former are derived from household surveys [101, 107], and the latter is initialized at its nominal value of unity. In addition, initial total and noncompetitive consumer good import coefficients are required for each sector. These have been derived from input-output data [16].

Investment

The investment subcomponent of NECON requires constant parameter data, for each of the 15 nonagricultural sectors, on profitability and capacity utilization elasticities of private net investment. For the mining and manufacturing sectors, these elasticities were estimated from time series derived from the Mining and Manufacturing Surveys [100]. Data for population and income elasticities in the residential construction investment function must also be supplied. These have also been estimated from time series data [15].

The **B** matrix, which converts investment by sector of destination into demands for investment goods by sector of origin, is computed in NECON on the basis of incremental capital-output ratios (ICORs) and relative prices. The matrix of ICORs, by sector of origin and sector of destination, must be supplied as constant parameters. These have been estimated for the NECON sectors from (1) the K. C. Han study [63] of capital coefficients, which is based on the 1968 wealth survey, and (2) an aggregation of the Korean Development Institute's 52-sector model [89]. Additional constant parameters required are trade and transportation margins for investment goods for each sector and lag times for investment gestation delays. The margins have been derived from input-output data [16].

Initial conditions required for the investment subcomponent are residential construction investment, private net investment, and capital stock in each sector. In addition, initial total and noncompetitive investment-good import coefficients are required for each sector. These have been derived from input-output data [16].

Production

Two sets of constant parameters are needed as data for the production subcomponent. Trade and transportation margins for exports of each sector are derived from input-output data [16], as are the interindustry input-output coefficients (except agriculture). Input coefficients for agriculture are computed by NECON on the basis of information from the agricultural sector model.

As initial conditions, total and noncompetitive intermediate input import coefficients, by sector of origin and sector of destination, are required. These have also been derived from input-output statistics.

Labor

Constant parameters needed to run the labor subcomponent are, for each sector except agriculture, the limiting values of unit labor requirements and the time constants governing the decay rate towards those limits (*FL* and τ in equation (5)). Also required for each sector are the proportions of total employment that are wage labor. Data from the Mining and Manufacturing Surveys [100] and input-output statistics [16]were used to estimate these parameters. Initial conditions of unit labor requirements and wage rates for each sector were derived from the same sources.

Price

Constant parameters required for the price subcomponent are, for each sector, trade and transportation margins for consumer goods, investment goods, and agricultural inputs. These have been derived from input-output statistics [16]. In addition, exogenous projections of producer and world price indexes are needed. All price indexes are initialized to unity in the model.

Accounting

Constant parameters that must be estimated for the accounting subcomponent are capital consumption allowance and indirect taxes per unit output for each sector (estimated from input-output data [16]) and income and import tax rates.

Variables that must be initialized are real gross domestic product for each of the ten years preceding the initial year. The latter are used in computing one-year, five-year, and ten-year average growth rates of GDP.

PRELIMINARY TESTING AND AREAS FOR FURTHER RESEARCH AND MODEL DEVELOPMENT

Preliminary testing of NECON, in isolation and as a component linked with the rest of KASM, has indicated several areas of further research and model development. The most important areas fall into three broad categories: price projections, private investment projections, and consistency of KASM linkages.

In earlier stages of model development, NECON attempted to project real (i.e., deflated) producer price indexes for each nonagricultural sector. Problems arose in doing this, because the deflated price index is not just a function of costs and capacity utilization, as was postulated, but also of the general price level, i.e., all other prices. To project nominal price indexes, however, would require consideration of the effect of government's monetary and fiscal policies on the general level of demand — clearly beyond the scope of KASM. Or, at least an exogenous variable, perhaps a time-trend factor, could be added to disposable income and/or public consumption to reflect that effect. Prices would then respond to the increased demand through the capacity utilization factor.

Another alternative — the one we have followed in the current version of the model — would be either to assume that real price indexes remain constant after the tracking period of the model (1970–75) or to project sector-specific price indexes exogenously. In fact, however, relative prices have *not* remained constant in the past. Furthermore, to continue 1975 price indexes as constant would be to project an abnormal condition in that the transient effect of the oil price shocks of 1973–74 would be maintained, instead of allowing the system to adjust towards a new equilibrium or "normal" condition. Clearly, the question of whether price indexes can or should be projected endogenously or exogenously bears further investigation.

Work that needs to be done with the private investment functions (see equation (3)) mainly involves tuning the elasticities, primarily the capacity utilization elasticities, so that investment in new capacity keeps pace with demand increases. Remember that there is no direct capacity constraint on production, but that net investment responds to capacity utilization (measured as the output-capital stock ratio). Assuming, as we do, that the ratio of *capacity* output (not actual output) to capital stock is constant, capacity utilization should stay close to its initial (1970) value or increase some, if capacity was underused in 1970. For some sectors, in preliminary tests, this is so; but for others capacity utilization projected by NECON increases two to three and sometimes five times over ten years, indicating the need for a faster rate of investment in the model for those sectors.

Finally, when NECON is run linked with the rest of KASM, inconsistencies become apparent between the microeconomic initial conditions for agriculture in KASM and the macroeconomic initial conditions for the agricultural sector in NECON. The latter are used when NECON is run independently, and the former are used when it is run linked with KASM. The result is that NECON behaves differently when run in the two modes. These problems are mainly related to exports, consumption of agricultural products, and agriculture's input-output coefficients and arise, at least partly, from the use of different sources for each set of initial conditions. KASM uses household surveys, customs data, and food balance sheets to initialize consumption and exports, whereas NECON is initialized from 1970 input-output data and national accounts. Further investigation is required to account for, and then reconcile, the discrepancies.

8
THE TECHNOLOGY CHANGE COMPONENT OF THE KOREAN AGRICULTURAL SECTOR MODEL

Jeung Han Lee

INTRODUCTION

The technology change component (CHANGE) of the Korean Agricultural Sector Model (KASM) deals mainly with farmers' production decisions in response to changes in technology. It models the processes determining how productivities or yield levels of crops under consideration change over time. These variables are determined in the real world by many different forces; CHANGE focuses on the effects of alternative public policies, programs, and projects.

The principal purposes of a sector model are (1) to capture the most important structural and behavioral relationships within the sector concerned and between it and the rest of the economy and (2) to help design development plans for the sector [167]. The public sector has been the leading force in economic and social development of the Korean economy, and this will continue to be true in the future. For the agricultural sector model to be useful in planning, it should clearly define how the specific, individual public policies, programs, and projects influence farmers' decisions in allocating resources at their disposal and, hence, aggregate performance of the agricultural sector. CHANGE models dynamic interactions between the public and farm sectors with respect to resource-use intensity.

This component model has several objectives. The first is to identify the sources of productivity growth or development. The classical economist emphasizes only economic variables; the agronomist, biological ables; and the engineer, physical variables as means of acceleratin nomic growth and development. An integrated model is required t comprehensive, consistent, and even optimal [172] with respect relevant variables. Individual factors are certainly not mutually excl they may be economic complements to each other. It is import identify the degree and extent of the interactions and contributi individual factors to economic growth and development. Then econ development strategies can be designed in the context of the dynami long run, rather than the static and short run.

Another objective of CHANGE is to illustrate how different the techniques, decision models, and quantitative methods can be inte gled to deal with practical problems involving dynamics. It is difficult, impossible, to develop by a single quantitative method a comprehe and consistent sector model dealing with the dynamic process of nomic development. As indicated in other chapters, each compone KASM is modeled using a unique quantitative technique. This is also for CHANGE and for each of its subcomponents.

Lastly, as already implied, we illustrate with this component s methodologies with which to model the dynamic process of econ development more accurately and realistically. By the dynamic proces mean the processes involving not only a time path of the variable cerned and a time lag or delay between causes and results, but uncertainty (see [84] for the managerial process). More specific CHANGE models dynamically (1) the process of innovation diffusio was done in [3], (2) the process of land and water development, (3) process of productivity growth on newly improved or developed land, (4) the process of production decision making.

OUTPUTS OF *CHANGE*

Let us now state more specifically what kinds of variables we inten project over time as outputs of this component model. These include following categories:

- I. Individual crop yields by region
- II. Factor inputs — intensity by crop and region
    - A. Fertilizer inputs
    - B. Chemical inputs
    - C. Other material inputs
    - D. Labor inputs
        1. Spring season
        2. Fall season
        3. Annual total

III. Agricultural land by region
   A. Total land area
      1. Paddy
      2. Upland
      3. Potential double-crop land
      4. Pasture land
   B. Land areas improved by the land and water development projects, by paddy or upland
      1. Irrigation
      2. Consolidation
      3. Drainage
      4. Reclamation
      5. Other improvements
IV. Investment requirements for individual land and water development projects

Some model outputs, such as investment requirements, are final outputs. Most, however, are intermediate variables needed to determine or project, directly or indirectly, the final performance variables of the global KASM system. The major linkages between CHANGE and the rest of KASM, including the public sector, are shown in Figure 22. In relation to the overall KASM structure, CHANGE is most directly designed to provide input to the resource allocation and production component (RAP). That is, the primary CHANGE outputs of yield and factor inputs are designed to be inputs to the objective function, input-output coefficients, or both of the RAP linear program model. The land capacity outputs of CHANGE, together with projections from other components such as the farm labor force from POPMIG, are designed to be inputs to the resource constraint vector of RAP. Essentially, CHANGE is constructed to make RAP completely dynamic and to link it with the public sector.

In addition, however, as seen in Figure 22, CHANGE supplies the national economy component (NECON) with (1) public and private investment made in the agricultural sector for land and water development, and (2) demand for specific inputs required for land and water development supplied by the farm and nonfarm sectors. In addition, CHANGE projects factor input use per unit of land for individual crops. These input rates are multiplied by the area allocated to each crop (determined in RAP) and then summed across crops to project total demand for individual production factors, as required by NECON.

INPUTS TO *CHANGE*

What kinds of variables are likely to influence the output variables stated above? Or what kinds of policy instruments is the public sector able

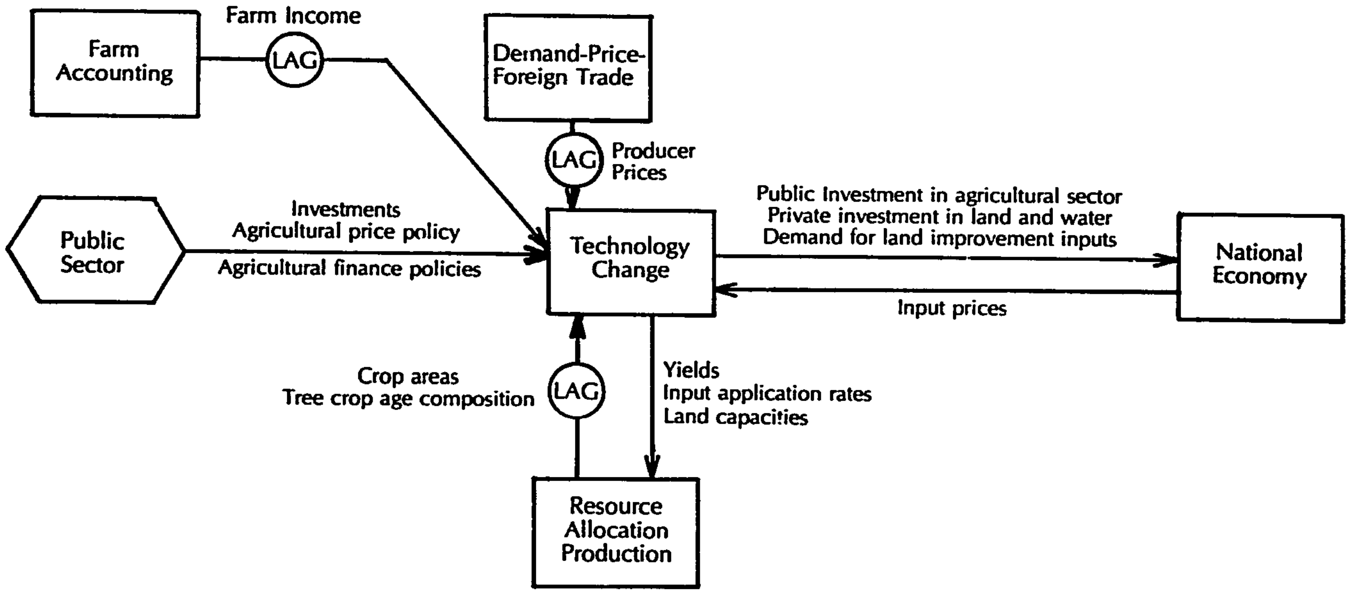


FIG. 22. Major direct linkages between the technology change component and the rest of the Korean agricultural sector model.

or authorized to use? The first two categories of output variables indicated above are farmer decision variables, not public decision variables. Then how do public decisions affect these variables? Let us list the specific public policy instruments considered in CHANGE:

I. Policies related to land and water development
   A. Land and water improvement
      1. Multipurpose, large-scale, land development projects
      2. Large-scale irrigation projects for paddy
      3. Small-scale irrigation projects for paddy
      4. Paddy consolidation projects
      5. Paddy drainage projects
      6. Improvement projects for low-producing paddy
      7. Upland irrigation projects
      8. Upland consolidation projects
   B. Land reclamation
      1. Tideland development projects
      2. Upland development projects
   C. Pastureland improvement program
   D. Policies on agricultural land conservation
II. Policies related to biological technology development
   A. Research programs
   B. Extension programs
III. Price policies
   A. Product price policy
   B Factor price policy
IV. Agricultural finance policies
   A. Credit program
   B. Interest policies

These are the policy instruments available to the public planner. They are exogenously determined, as represented by a hexagon in Figure 22. It is not claimed that these are the only policies that the public sector can use to change the resource base and input-output coefficients for agricultural development, but they are considered the most important, and they are directly related to productivity growth.

There are input variables other than policy inputs that affect productivity growth, directly or indirectly. By definition, these kinds of input variables must either be determined exogenously or supplied from other KASM components. The inputs to CHANGE that are generated as output variables of other components are shown in Figure 22. Most of these inputs are not current but are one-year lagged variables (noted as LAG). This type of input includes (1) regional specialization (computed from crop areas), (2) change in age composition of tree crops, (3) farm capital formation (computed from farm income), (4) producer prices, and (5) factor input prices. Prices generated in DEMAND and NECON are determined by market forces.

In addition, there are variables generated within CHANGE as intermediate or state variables that relate input and output variables. Some of these variables will be discussed in the following section.

In summary, agricultural development involves technological, institutional, and human change. Such change or transformation depends basically on investment in agriculture. Both components, CHANGE and RAP, deal with investment problems on the production side. The former concerns itself mainly with public investment in the form of direct investment, subsidies, or finance, and the latter determines the level of farmers' investment or capital formation for such items as farm machinery, livestock, and perennial crops.

STRUCTURE OF *CHANGE*

Following is a discussion of how the output variables are projected, based on the model inputs indicated in the previous section. A simplified version of the model structure is shown in Figure 23. The component consists of five subcomponents, in addition to the public sector:

1. Land and water development
2. Biological research
3. Innovation diffusion
4. Factor demand projection
5. Product supply projection

The Product Supply Projection Subcomponent

First let us discuss the mechanism of individual crop yield projections. By explaining the final variables first and the causal variables last, we hope to increase the reader's understanding.

The production rate (and hence supply) is exclusively a response to resource use. Thus, once the input rates are determined each year and the production function is known, it then becomes a computational problem to project individual crop yields. This is basically the production function approach. The price-output relationship, or supply function approach, is not used for several reasons [80]. First, agricultural supply cannot be accurately explained with price variables alone. As shown in Figure 23, factor input levels (conventional as well as nonconventional) determine the production rate [82]. Input and output prices affect output level through factor demand. But prices are only one of several kinds of variables that affect (conventional) factor demand. Second, regression approaches to supply analysis based on price-output relationships are known to be imper-

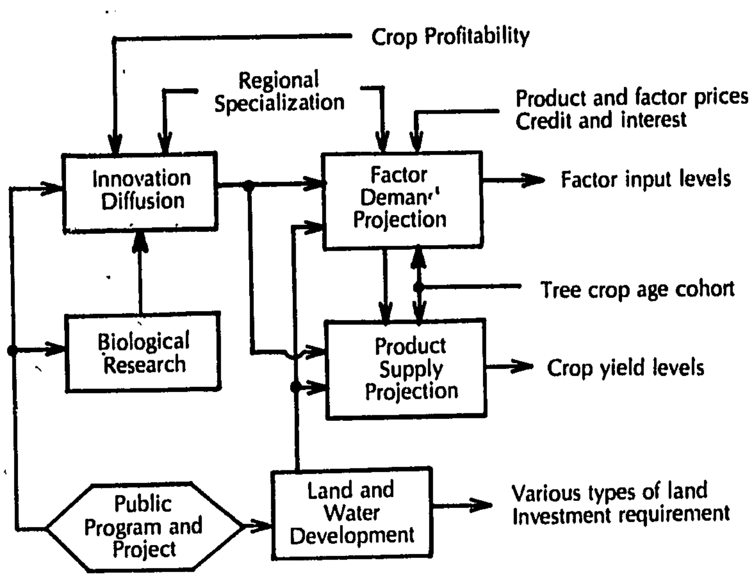


FIG. 23 Internal structure of the technology change component.

fect, especially when structural changes are present [114]. As a matter of fact, one of the primary objectives of an agricultural development plan is to change the input-output coefficients associated with agricultural production [49]. Much of this change can only be attained through technological, institutional, and human change, i.e., structural change. Third, positive price policy alone can do little to increase total farm supply, especially in the short run, from a low-level, stationary, equilibrium state. For most crops, the so-called conventional inputs in Korea are being used at the appropriate rates for maximum physical production [116], perhaps because of input price subsidy and credit programs.

This argument implies that there is not much room for price policy to be effective in increasing the output rate, unless structural change takes place to shift the short-run production function. At any rate, our production function for yield Y_{ij}, is represented as

$$Y_{ij}(t) = f[X_{ij\ell}(t), Z_{ijk}(t)] \tag{1}$$

where i indexes regions, j crops, ℓ conventional inputs, and k nonconventional inputs. Conventional inputs ($X_{ij\ell}$), such as fertilizer and pesticides, are basically supplied from the private sector, including the farm sector itself. Nonconventional inputs (Z_{ijk}) are structural change variables. Two types of nonconventional inputs are distinguished. One is inputs that the public sector supplies to the farm sector directly or indirectly through investment, subsidy, or loan programs. Examples include high-yield varieties, new cultivation practices, improved land, better institutions, and human capital. The other is the capital generated in the farm sector that affects the yield level. An example of this type of input is perennial crops (fruit trees and mulberries in the KASM system); that is, age composition of tree crops and status of plant health. Age composition of tree crops is computed in RAP and plant health is internally computed in CHANGE, assuming that the status of plant health is dependent upon past input use.

In actual computation, we use the following projection equation:

$$Y_{ij}(t) = \left(1.0 + \sum_{\ell} \alpha_{ij\ell}(t) \frac{\dot{X}_{ij\ell}(t)}{X_{ij\ell}(0)} + \sum_{k} \beta_{ijk}(t) \frac{\dot{Z}_{ijk}(t)}{Z_{ijk}(0)}\right) Y_{ij}(0) \qquad (2)$$

where $\dot{X}(t) = X(t) - X(0)$, $\dot{Z}(t) = Z(t) - Z(0)$, and αs and βs are appropriate elasticities. This form of equation can be derived from any form of production function by means of the Taylor series expansion.

Factor Demand Projection Subcomponent

In order to project individual crop yields, we must first project the levels of the conventional, as well as nonconventional, inputs used for individual crops. In this subsection we will discuss how the so-called conventional input demand is projected. The nonconventional input uses will be discussed in the following subsections.

Conventional inputs considered in CHANGE are fertilizer, chemicals, other material inputs, and labor. What are the determinants of factor demand? We have seen that product and factor prices influence the production rate and, hence, supply. That is, farmers' response to price is actually revealed in the level of factor use. Indeed, supply response is really a factor demand problem.

Input-use intensity is also affected by technical relationships. In a dynamic process, such as the system presented here, these coefficients are changed over time. Structural change variables act as production-function shifters, as well as shifters of factor demand. To change these coefficients is a major purpose of a development plan.

In the model the individual factor demand function for each crop is constructed as a function of the economic and physical variables considered above, as shown in Figure 23. However, because of lack of appropriate time series data, we derive (conventional) factor demand functions from the production functions. Here we adopt the so-called profit maximization assumption. The optimum input level — hence, output — derived under this assumption is often believed to be the upper bound of actual performance [171]. Model estimates, therefore, are likely to be high, because all important constraints that farmers actually face are probably not considered in the model conceptualization. Thus, in order to make our projections more realistic, we impose several restraints in terms of finance, uncertainty, and resource fixity. These financial restrictions are that (1) total expenditure cannot exceed total supply of the capital budget; (2) credit used from all sources (own capital, credit from public institutions, credit from private moneylenders) cannot exceed the respective supplies; (3) the marginal rate of internal return to capital cannot be less than the appropriate interest rate; and (4) farmers' own capital may be disposed of in nonfarm uses, if desired, so that the marginal rate of internal return is equal to the salvage interest rate. To represent uncertainty and resource fixity restraints, factor demand elasticities with respect to prices are adjusted to reveal the direction, duration, and magnitude of price changes.

The resultant factor demand function derived from the profit function and constrained by production functions and the conditions specified above is represented in equation (3),

$$X_{ij\ell}(t) = \Big(1 + \alpha_{ij\ell}(t)\,\frac{\dot{P}_{y_{ij}}(t)}{P_{y_{ij}}(0)} + \sum_n \beta_{ij\ell n}(t)\,\frac{\dot{P}_{x_{in}}(t)}{P_{x_{in}}(0)} + \gamma_{ij\ell}(t)\,\frac{\dot{\varepsilon}_i(t)}{\varepsilon_i(0)} + \sum_k \delta_{ij\ell k}(t)\,\frac{\dot{Z}_{ijk}(t)}{Z_{ijk}(0)}\Big) X_{ij\ell}(0) \tag{3}$$

where $X_{ij\ell}$ stands for use of input (ℓ) for crop (j) in region (i); $P_{y_{ij}}$ for price of crop (j) in region (i); $P_{x_{in}}$ for factor price of input (n) in region (i); the $\dot{P}$s, $\dot{\varepsilon}$s, and $\dot{Z}$s are appropriate time derivatives; and α, β, γ, and δ are appropriate coefficients. Equation (3) is still a partial solution, since it contains at least one unknown variable, ε, besides the Zs. This variable is a Lagrangian multiplier plus one and is equivalent to the gross marginal rate of internal return to capital or, in this formulation, the marginal value product per unit of expenditure (MVPUE). We need to determine the value of this variable to project the so-called conventional input levels, $X_{ij\ell}$.

By substituting individual factor demand functions for all crops into the overall budget constraint and solving it in terms of ε, we have

$$\varepsilon_i(t) = \frac{\varepsilon_i(0)}{\sum_j\sum_\ell \gamma_{ij\ell}(t) X_{ij\ell}(0)} \Big(1 + \sum_j\sum_\ell \alpha_{ij\ell}(t)\frac{\dot{P}_{y_{ij}}(t)}{P_{y_{ij}}(0)} + \sum_j\sum_\ell\sum_n \beta_{ij\ell n}(t)\frac{\dot{P}_{x_{in}}(t)}{P_{x_{in}}(0)} + \sum_j\sum_\ell\sum_k \delta_{ij\ell k}(t)\frac{\dot{Z}_{ijk}(t)}{Z_{ijk}(0)}\Big) - \varepsilon_i(0) - \frac{\varepsilon_i(0) B_i(t)}{\sum_j\sum_\ell \gamma_{ij\ell}(t) P_{x_{i\ell}}(t) X_{ij\ell}(0)} \tag{4}$$

where B is total supply of capital in the budget for region (i). Equation (4) can be interpreted as the demand function for the capital budget. Once $B_i(t)$

is given, we can project the factor input levels through equations (3) and (4). The first financial restraint listed above can be met through equation (4); however, there is yet no guarantee that specifications 2, 3, and 4 will hold. Let us see what we can do.

First of all, the capital budget, $B_i(t)$, is made up as follows:

$$B_i(t) = F_i(t) + G_i(t) + P1_i(t) + P2_i(t) \tag{5}$$

where F stands for farmers' own capital, G for government-supplied credit (short-term), and $P1$ and $P2$ for private moneylender credit with low and high rates of interest respectively. This means that the credit supply is a step function, as illustrated in Figure 24, where

$$B1_i = F_i,\ B2_i = F_i + G_i,\ B3_i = F_i + G_i + P1_i, \text{ and}$$
$$B4_i = F_i + G_i + P1_i + P2_i$$

We have not decided yet how much capital should be used. Should we use capital in the amount of $B1, B2, B3, B4$, or in some amount between $B1$ and $B2$ in Figure 24, for example? The guidelines for this decision are given in specifications 2, 3, and 4, stated above.

In order for these conditions to hold and for capital use to be determined, we play a game. That is, we start with $B1$ and compute the ε or MVPUE by equation (4) to see whether or not a farmer's own capital is fixed or whether the farmer needs to borrow more or to dispose of some of his own capital. This game is illustrated in Figure 24. If the ε turns out to be MVPUE1, he uses his own capital in the amount of $D1$ and disposes of the surplus $(B1-D1)$, so that ε is equal to $R1$, which is the salvage interest rate plus one. If ε with $B1$ is equal to $R1$ or greater than $R1$ but less than $R2$ — which is the government interest rate plus one — then his own capital is fixed by definition. This is a case illustrated by MVPUE2. Otherwise, he needs to examine whether or not to borrow money from government-supported institutions, which are the chief credit-granting institutions. This game is continued until all four specifications hold. By playing this game, the amount of capital budget needed and the appropriate marginal rates of internal return to capital are simultaneously determined. Now we are ready to project individual factor input demands; but there is still an unexplained variable, Z, in equation (3).

Land and Water Development Subcomponent

Now we must explain how the so-called structural change variables, Zs, which are supplied directly or indirectly by the public sector, are determined. We distinguish two types of this variable: land quality change and biological technology change. The former is discussed in this section. The land quality change is a consequence of land and water development projects, the various types of which are listed in an earlier section. The

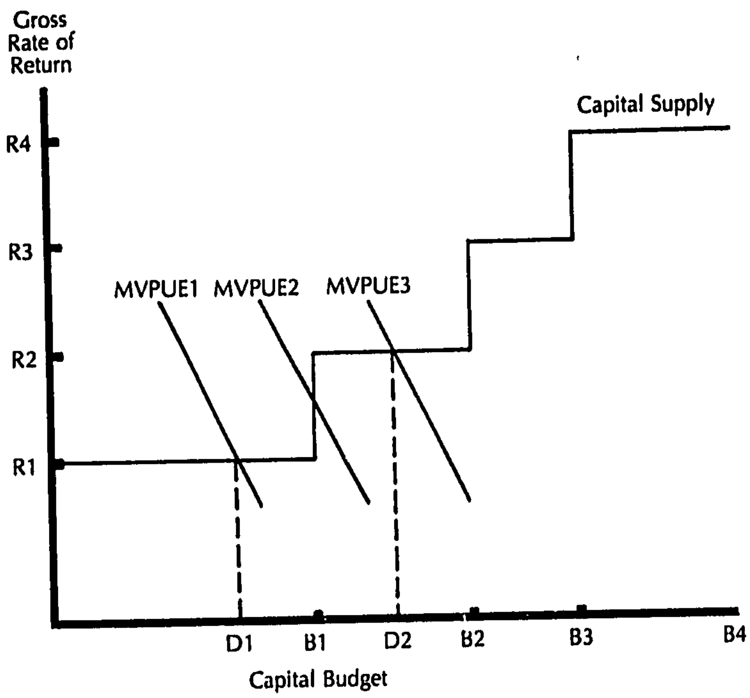


FIG. 24. Demand function for and stepped supply function of capital budget (for illustration).

kinds of farmland included in these land and water development projects are classified as follows:

1. Paddy administered under irrigation associations
2. Irrigated paddy
3. Partially irrigated paddy
4. Rain-fed paddy
5. Drained paddy
6. Consolidated paddy
7. Improved paddy
8. Developed tideland
9. Irrigated upland
10. Consolidated upland
11. Unirrigated upland
12. Developed upland
13. Improved pasturage
14. Unimproved pasturage

These kinds of farmland are not necessarily mutually exclusive. For example, irrigated paddyland also could be drained and/or consolidated paddyland. Some possible kinds of land are not listed; for instance, undrained paddyland, unconsolidated paddy- or upland, etc. These are omitted here because we need only totals of paddy, upland, and pasturage and the proportions of improved land. We need to distinguish all these types of farmland because each has a different effect in shifting production and factor demand functions. Also, each contributes differently to an increase in potential double-crop land.

In most cases, the reader will easily see the correspondence between the types of land listed above and the policy input variables stated earlier. However, some additional discussion is in order. First, multipurpose, large-scale land development projects are assumed to provide simultaneously irrigation, consolidation, and drainage for paddyland, as desired, and possibly tideland or upland development. Thus, such a project augments the productivity of improved land while transforming unimproved land to improved land or one kind of land to another.

Second, large-scale irrigation projects, like multipurpose projects, are sponsored by the central government and augment the paddyland-under-irrigation associations. Small-scale irrigation projects are undertaken by local governments to augment the irrigated paddyland. In both cases, some idle land or upland located near the paddy will likely be transformed into paddyland during the process of project implementation. Third, a certain amount of farmland is transferred annually to other uses because of urbanization, industrialization, and so forth.

With this introduction, a simplified computation of mix of land types can be represented by

$$LAND_{ik}(t) = LAND_{ik}(0) + \int_0^t [A_{ik}(t) - \propto_{ik} T_i(t)]dt \tag{6}$$

where A_{ik} is the rate of change in the land base in which the productivity is increased after improvement due to project (k) in region (i) in year (t), T_i is the rate of land transferred to other-than-farm uses in region (i) year (t), and $\propto_{ik}$ is a parameter. In some cases, the potential productivity gain is obtained immediately after land improvement; in other cases, it is not. Examples in which delayed increase in productivity occurs include tideland, developed upland, consolidation, etc. In cases of tideland, it takes more than five years after completion of the project for the potential productivity to be reached. This phenomenon can be modeled by either difference or differential equations, depending on assumptions made about the distribution of the time delay. Using a difference equation,

$$A_{ik}(t) = B_{ik}(t - T) \tag{7}$$

where B stands for the rate of change in the land base just improved in which potential productivity is not yet reached, T indicates the number of years required to reach the potential productivity gain.

There is also some time lag or delay between initiation and completion of a project. This land improvement time lag can also be modeled by either difference or differential equations. Using a differential equation, this can be represented as follows:

$$k\left(\frac{D}{k}\right)^{k}\frac{dB(t)}{dt}+k\left(\frac{D}{k}\right)^{k-1}\frac{d^{k-1}B(t)}{dt^{k-1}}+\ldots+k\left(\frac{D}{k}\right)\frac{dB(t)}{dt}+B(t)=E(t) \quad (8)$$

where D is the expected average delay — number of years to complete a project, k is the parameter describing the shape of distribution of project completion times, and E is the rate of land scheduled for improvement (policy variables) in each year. Note that subscripts denoting regions and projects are omitted to avoid complication. When $k = 0$ in equation (8), $B(t) = E(t)$, which implies that land is instantaneously improved. When $k = 1$, equation (8) reduces to the first-order differential equation, $D^*dB(t)/dt + B(t) = E(t)$, which means that the completion times of projects implemented are exponentially distributed. As k increases, the distribution of completion times approaches a normal distribution; and if $k = \infty$, the distribution is normal with mean D and zero variance, and equation (8) reduces to a difference equation like equation (7), $B(t) = E(t - D)$, which implies a discrete delay where all land is improved exactly D years after project initiation.

For either equation system, there are several computer programs that provide numerical solutions. Each program preserves the intermediate rate of land development, that is, land areas by development stage. This information is used (1) to compute the annual investment required for land and water development, with information on project costs required by development stages, and (2) to deal with the process of productivity growth on the newly developed land.

In summary, the Zs in equations (1) to (4) are not measured in terms of absolute area, but in terms of proportion of improved land to appropriate total areas. As an example, suppose half of the [illegible] paddyland in a region is well drained. Then the Z value for the categ[illegible] becomes 0.5. This expression is necessary because we are concern[illegible] with the regional average yield, not with the total production of a crop. Now, suppose the productivity difference between drained and undrained paddyland is one ton per hectare. Then the Z value of 0.5 implies that the average production function shifts up by one-half ton per hectare, as compared to that for undrained paddyland. When every piece of paddyland has been well drained, the function will have shifted up by one ton. (This numerical example is just an illustration.)

The Biological Research Component

No one would deny that change in biological technology is the most important, powerful measure in increasing farm production, especially in the Korean agricultural setting. Unfortunately, the progress and effect of biological technology modeled in this subcomponent are the most difficult phenomena considered by CHANGE to represent mathematically and accurately. Research and education are not purely stochastic phenomena, with chance occurrences relative to their initiations and outcomes. The probability of scientific discovery for a particular product, function, or service depends on the quantity and quality of resources allocated to it [66]. But the economics of biological technology changes remains one of the least-developed areas in economics, both in theory and application [69]. Despite much work on the economics of biological research, the common conclusion reached seems to indicate that social returns to public investment are high.

Let us ask ourselves when a particular research outcome with a certain productivity gain would materialize if a certain level of research resources were allocated over a certain period of time. A definite answer is not possible even though the new rice varieties, such as Tong-Il, Yoo-Shin, Mil-Yang Nos. 22 and 23 in Korea, and many other biological technologies are merely research outcomes that came about through public investment. While we know of such successful cases, we also know that many unsuccessful cases also exist. It is risky to predict research outcomes in advance in terms of the point in time at which they will materialize, the degree of productivity gains, and other biological properties.

To deal with this difficulty, we adopt a simplified assumption that during the planning horizon, a series of biological technologies, such as a new variety or cultivation practice, will materialize with certainty at specified points in time and with specific levels of productivity gains at the experiment station for all crops under consideration. This is illustrated in Figure 25.

This assumption may or may not hold in reality, depending on the research investment allocated and the other variables involved. We treat the assumption made in Figure 25 as a basis for sensitivity analysis. This will provide information on the consequences of alternative assumptions about biological technology development on the performance of the farm sector.

Through this sensitivity analysis, we obtain information on the desired rate of change in biological technology needed for achieving certain policy goals. In turn, this information can be used in designing and directing research programs. Suppose we have tentatively concluded that it is desirable to develop a series of new varieties that would increase productivity of a crop by 50 per cent, say, by 1985. If it is found technically feasible at reasonable cost, then an investment will be made. If it is concluded not to be feasible, then several alternative policies can be examined: (1) the

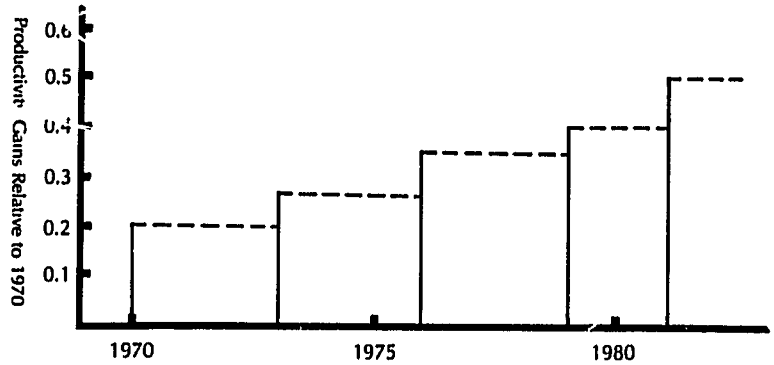


FIG. 25. Hypothetical illustration of the points in time that new crop varieties appear and their experiment station productivity gains relative to 1970 yield levels.

possibility of developing new varieties of substitute crops, (2) the possibility of obtaining the same goals by investing more for land and water development, and (3) the economic feasibility of importing food through international trade by expanding export industries, etc.

The Innovation Diffusion Subcomponent

After accepting the assumption made in Figure 25, we turn to modeling the process of adopting the technology made available. The new rice variety named Tong-Il, having a gain in productivity of about 30 per cent, appeared at the experiment station in 1970. Dissemination was started on this variety in 1971. Despite an intensive government program, the total paddy area in which this variety was adopted was only about 40 per cent by 1975. What would be the implication of this fact? Why do all farmers not adopt this variety on every piece of paddy? Basically, there are two reasons: imperfect knowledge involving uncertainty, and limited area for which the new technology can be advantageously adopted. In connection with these reasons, several points must be considered: (1) the potential maximum area of farmland in which a new technology could be advantageously disseminated, (2) the speed of adoption, (3) factors accelerating the diffusion rate, and (4) actual (average) productivity gain at the farm level.

Before explaining the subcomponent structure, several remarks are in order. Both subcomponents, land and water development and innovation diffusion, are modeled basically by a differential equation system. Nevertheless, they are very different systems in many respects — the former is a physical process, whereas the latter is a social process. Thus, the latter requires equations and parameters describing farmers' behavior. Sometimes their behavior is not exactly known. In this sense, it may be difficult to model the structure of and estimate parameters for this subcomponent.

In the case of the land and water development subcomponent, we implicitly assume that production factors (land quality) supplied from the public sector are instantaneously demanded by farmers; that is, supply is always equal to demand. However, we cannot make this assumption in modeling the diffusion process. Because of the uncertainty involved, farmers do not necessarily instantaneously adopt a new technology that is supplied. This is a disequilibrium system in the short turn. However, we adopt Cochrane's "treadmill" hypothesis [33] in the long-run context, insisting that average farmers eventually will adopt a new technology that is made available.

Potential Maximum Area to Which a New Technology Can Be Adopted. A new technology should be better than the old in terms of its yield level, lower production cost, or some other production-improving characteristic. However, there is no guarantee that a new technology contributes to, say, a higher yield in all cases. That is, it may be better only for certain locations, weather conditions, farmers, and farmland that have particular characteristics. For a given new technology, the potential area to which it can be adopted can be extended by training farmers, improving farmland, and so on. Despite this, we assume that until more information is available the maximum potential suitable area is constant for each technology (k) shown at different points of time for each crop (j) in each region (i).

The Process of Technology Diffusion. When will adoption of each new technology be completed? Or, how long will it take to complete adoption? It is known that the adoption curve or diffusion rate distribution has a bell-like shape and approaches a normal distribution. This process can be modeled with a higher-order differential equation, such as equation (8) above. Then, in this case, $B(t)$ will be areas to which a new technology is completely adopted in year t. D will be the expected average time between introduction and adoption. The shape of the distribution is again characterized by k. Finally, $E(t)$ stands for areas introduced to the new technology in year t.

In the process of diffusion, we adopt Campbell's "adoption tree" hypothesis [28], which implies that (1) trial does not necessarily mean adoption; (2) it may take more than one year to decide completely to adopt; and (3) one may try it several times before adoption. Rejection after trial is called the dropout rate. This rate, the expected average delay, and the rate of land area entering the adoption process are assumed to be functions of public investment (budget for extension), the degree of regional specialization, profitability, and the importance of a crop in a region.

Productivity Gain at the Farm Level. Once the rate of adoption in each year is determined, we are ready to compute both the accumulated area by integration and the regional average gain in productivity, since we know the area adopted and productivity gain expected. We may realistically assume that (1) the resource base and goals of farming on the average farm are less favorable than those at the experiment station, and (2) farms with a good resource base or equipped with better knowledge would adopt a new technology first. This argument then implies that (1) actual average gain in productivity at the farm level is likely to be less than on the experiment plots; and (2) as a new technology is disseminated among farms, the productivity gain on individual farms will decline [47]. That is, the regional average gain in productivity because of a new technology is treated as a decreasing function of accumulated land area to which that new technology is adopted, with an intercept that is smaller than the productivity gain at the experiment station.

Innovation Made Available from the Nonpublic Sector. It is obvious that some farmers act more or less as innovators in selecting seeds, using production factors, or applying husbandry suitable to their specific farm or farm location. Other farmers imitate the progressive farmers. On the other hand, the agribusiness firm that supplies the farm sector with modern inputs or processes farm products engages in research and development and also disseminates findings to farmers. It is assumed that (1) all this indigenous innovation occurs continuously, and (2) the rate of diffusion of this innovation is an increasing function of public investment.

SUMMARY OF THE MODEL STRUCTURE

Going back to equation (2), the structural change variables, the Zs, other than the ones internally computed, are determined in each year through the mechanisms specified in the last three sections. The levels of these variables basically depend on the levels of policy input variables. These Zs are in turn fed into equation (4) with other policy variables, such as credit and supported prices, to determine the marginal rate of internal return to capital, ε. Then this rate, ε, the Zs, and the supported prices are fed into equation (3) to determine the so-called conventional input demand levels in each year. By this process all production factors specified in equation (2) are projected. Thus, yield levels of individual crops can then be projected.

DATA REQUIREMENTS AND PARAMETER ESTIMATION

The structural relationships and their parameters will determine jointly the behavior of a system model. We have seen in the previous section that

CHANGE is a complicated and heterogeneous system. This fact induces us to require many different kinds of data from diverse sources and varying estimation techniques. Three kinds of data are required: parameters, exogenous variables, and initial conditions.

Parameters

Basically, the parameters to be estimated are of three types: behavioral, physical, and accounting. The most critical parameters that seem to dominate the behavior of CHANGE as well as the whole system of KASM are, first, the physical production relationships. These include productivities of the so-called conventional inputs and the degree to which the nonconventional structural factors shift the short-run production and factor demand functions. The former is indirectly estimated, mainly because of data problems. Individual factor shares are used as proxies for their respective productivity elasticities. For the latter, data come from many sources such as case studies or experiments. The parameters used for these productivity coefficients are, in a sense, synthesized. Essentially the same sort of technique is used for estimating factor demand elasticities with respect to structural change variables.

The second group of crucial parameters are the behavioral parameters that relate price and financial variables to factor demands. Again, these variables are indirectly estimated because of the same data difficulties. These parameters are really derived from the production function, as stated in the text.

There are other types of behavioral parameters related to farmers' behavior in adopting new technologies. Since this behavior is not well understood and no previously collected data are available, once again we had to use tentative data, inferred from the real world. However, while individual subcomponent models were built and tested, these parameters were more-or-less justified.

We have still other types of physical data, most of which are essentially engineering data related to land and water development projects. The basic set of these data was supplied from the Agricultural Development Corporation (ADC) and was based on engineering field surveys and experiments. The ADC uses this data set for making policy recommendations and for developing implementation plans for land and water development projects. The kinds of data included are (1) completion time of a project, (2) shape of the completion time distribution, (3) unit costs of project implementation, (4) productivity growth on newly improved or developed land, (5) time required for productivity maturity, (6) investment required by land development stages, and many others.

Exogenous Variables

We discussed the policy input variables earlier. These are, of course, exogenous variables to CHANGE and KASM. There are still other types that are exogenous either to CHANGE, exclusive of KASM, or to KASM. The former includes age cohorts of tree crops, the degree of regional specialization, etc., which are computed directly or indirectly from endogenous computed in other KASM components. Those exogenous to variables computed in other KASM components. Those exogenous to KASM include (1) the maximum potential farmland area needing improvement by various land and water development projects and (2) development costs. Information on these variables was also supplied by ADC. Another group of inputs exogenous to KASM is information on farmers' own capital and noninstitutional private loans made available for agriculture. Again, because of a data problem, primitive assumptions were made on the value of those variables.

Initial Conditions

Since CHANGE is a dynamic model, the initial conditions play an important role in determining the system behavior. Because CHANGE is a heterogeneous system, diverse initial conditions are also required. These include various classes of land, yield levels by crops, factor input levels by crops, prices by crops or production factors, age composition of tree crops, and many others. Basically, appropriate statistics in 1970 (the base year) appearing in the official government publications are used. However, some data are not available in official statistics. A typical example is factor uses, especially for crops other than rice, barley, and wheat. Thus, in many cases, information synthesized from many different case studies is used.

In sum, since CHANGE is quite sophisticated, synthesized, and complicated, there is no way to estimate all parameters simultaneously. This is true even for the production function for a crop in a region. Thus, the method and techniques used to estimate separately each of the parameters shown varied widely, from simultaneous estimation of subsets of data to "guesstimates."

TESTING OF *CHANGE*

CHANGE was extensively tested while being developed and in the process of sensitivity analysis and policy experiment runs. The philosophical basis of the model testing rested heavily on an objectivity or credibility test (see chapter 2 and also [83]). Because of the nature of the system modeled, historical verification alone was impractical.

First, checks were made to determine whether or not variables had correct signs, behaved appropriately, and remained within known bounds.

In addition to this, while conducting sensitivity tests that included policy experimental runs, we found that not all the relevant variables responded appropriately to changes in parameters or policy input levels. Whenever inappropriate responses were detected, a relevant part of the system model was corrected. This process was repeated until the model worked reasonably well. This type of procedure was first used for testing individual subcomponent models of CHANGE and then for testing the whole CHANGE model together after individual subcomponent models were linked.

Finally, some of the major model outputs were contrasted with historical data. In these runs, the values of policy inputs and other exogenous variables used actually prevailed in the real world. However, some statistical data were unavailable or published incorrectly and inconsistently. Differences between actual or historical and projected values should be interpreted as reflecting random error due to weather conditions and errors due to incorrect input data, in addition to possible misspecification of the model structure. An example comparison for rice yield is shown in Figure 26. It should be kept in mind when interpreting the projection made beyond 1975 that the projected value is exclusively the function of assumed policy input levels.

Historical tracking before the base year, 1970, may be desirable for at least the key major output variables. On the other hand, model behavior during the period representing the low-level, stationary equilibrium state of Korean agriculture may not be used as evidence for a dynamic agriculture, where structural transformation takes place. Structural transformation in agriculture has only been a serious goal in Korea since the Third Five-Year Plan, 1972–76. For these reasons, in addition to constraints we have on resources, we did not try such historical tracking.

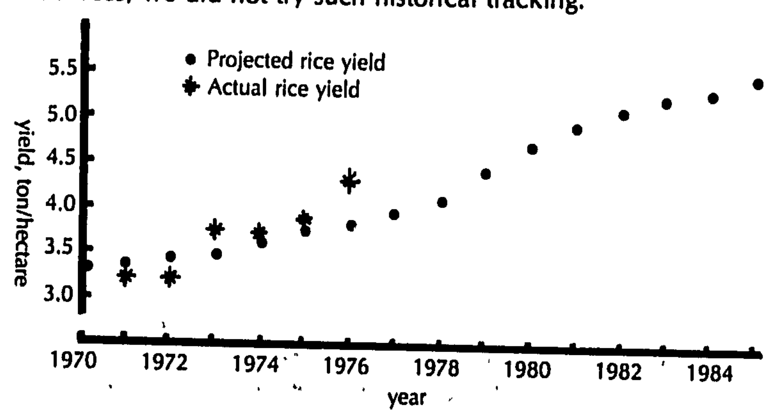


FIG. 26. Projected and actual yields for rice, as an example, based on sample run.

TABLE 2
Sources of Productivity Growth Rate
in the Average Rice Yield (in Percentages)
Relative to the 1970 Yield Level
(Based on Sample Run)

Year	Due to Change In				
	Conventional Input Uses	Land and Water Development*	Research and Extensions+	New Land‡	Total
1971	0.6	0.2	0.7	...	1.5
1972	0.4	0.3	2.0	...	2.7
1973	1.0	0.4	3.5	−0.1	4.8
1974	1.5	0.6	5.8	−0.1	7.8
1975	2.6	0.8	9.1	−0.1	12.4
1976	3.2	1.1	11.4	−0.1	15.6
1977	3.7	1.5	14.3	...	19.5
1978	4.7	1.9	17.5	0.4	24.5
1979	4.[illegible]	2.8	21.1	0.6	29.3
1980	5.3	3.8	27.1	0.4	36.6
1981	5.6	4.6	31.6	0.6	42.4
1982	5.9	5.0	35.5	−0.9	45.5
1983	6.1	5.0	38.3	−2.1	47.3
1984	6.2	5.0	41.1	−3.0	49.3
1985	6.9	5.0	45.3	−3.4	53.8

*This source has three different effects on the average yield: first, it may increase it (irrigation, drainage, and low-productive paddy improvements); second, it may decrease it (tideland development); and third, it may have neutral impact (paddy consolidation). The figures in this column are averages of these three forces. Thus, it is not appropriate to evaluate land and water development projects in terms of average productivity only.

†Sum of changes in biological technology made available by both public and private sectors.

‡Productivity change due to change in land in the stage of productivity growth. Remember that (1) for consolidation, for example, the yield level decreases in the first year after project completion and then starts to grow toward the normal yield; but (2) for drainage or low-productive paddy improvement, the yield level starts to grow from the first year toward a higher level than the normal yield.

Finally, Table 2 shows the sources of yield increase for rice as an example. The table corresponds to the yield levels in Figure 26. Biological technology appears to be the most powerful engine for productivity growth. Thus, we may conclude that whether or not the yield level increases over time sufficiently to achieve development goals depends on the rate of change in biological technology, especially for a country where the man/land ratio is high.

However, we should keep several points in mind when drawing this conclusion. Improvements in land and people are neither substitutes for, nor supplementary to, but rather economic complements of, biological innovation in the dynamic process of development [155]. It should also be realized that a supply of the so-called conventional inputs must be available to support this innovation for it to be effective. One should notice that a positive price policy and finance program would be more effective in this dynamic process than in the static equilibrium state and would become a complement to, not a substitute for, biological innovation.

This conclusion is rather general. Our critical concern then becomes whether it is possible to invent a series of, for example, new seeds for a desired crop so that development goals can be achieved. From the beginning, we emphasized a comprehensive and consistent sector planning activity. One of the most important responsibilities of the model builder, after a comprehensive model is constructed, is to work with other analysts and decision makers to design and develop strategies that meet consistency and optimality criteria.

Now let us be more specific. Would continuation of the present food consumption pattern of rice be consistent with the production possibility of rice in Korea in the future when a larger population, greater per capita income, and less farmland and labor are expected? Is the breeding for the small grains, such as rice, comparatively easier than that for other grains? Research activity is rather a risky enterprise. It is known that it is much easier to breed for a crop that has roots, leaves, or stems that are used for food or feed — such as potatoes, vegetables, or forages. Then the question is, which kinds of crops are easier to breed within the Korean agricultural setting that, at the same time, will meet other consistency and optimality criteria?

Since feed grains will become relatively more important and livestock products are substitutes for food grains in consumption as well, we chose potatoes as an alternative to rice or other small food grains in the breeding program and demonstrated in another paper [118] that this program would be more likely to contribute to meeting total grain requirements (food as well as feed) and even an improved diet.

NEEDS FOR FURTHER IMPROVEMENT IN THE MODEL

In an earlier section, we noticed that CHANGE requires tremendous amounts of data from diverse sources in order to estimate desired parameters or other variables. The data base of CHANGE now used is rather poor. The first priority for further model improvement should be given to improving the data base. In fact, data should be continued to be updated as new and better sources become available. For the model to remain useful for an ever-changing system, the model structure must also be updated.

In addition, several segments of the model structure should be more fully understood. We have included several simple behavioral relationships in the model, such as innovation of new technologies, the farm consumption-saving-investment relationship, the noninstitutional private money market structure, and the real price behavior — including interest rates, etc. This is only a partial list.

Several other policy or environmental variables might affect major output variables of CHANGE. Examples include improvement in transportation and market systems, rural electrification or other infrastructure improvements, and changes in farm size and in migration patterns. The effects of these variables on agricultural production, as well as on rural development, should be better understood.

The so-called conventional production factors are now mainly recognized as an economic complement to the nonconventional inputs in the process of agricultural development. The energy crisis, as we all know, has had a great impact on the input supply sector in terms of supply prices, quantity, and even quality supplied. On the other hand, the agricultural market system in Korea is relatively undeveloped, and its value added contributes a relatively small portion to the total value of food supplies. However, it is expected that the role of the market, especially the processing subsector, will become more imponant as economic development proceeds. In other words, the roles and functions of input supply and product processing subsectors may need to be understood in relation to farm production, production rates, and overall rural development.

In conclusion, it appears that any kind of problem-solving model obviously faces a data problem, as does CHANGE. The data set presently used for CHANGE is essentially the same as that used when the public decision maker produces a practical plan or when a pencil-and-paper projection is made by using some sort of informal model. The essence of CHANGE is, thus, basically very similar to the traditional informal methods in terms of methodology used. But CHANGE contains more economic and behavioral relationships and attempts to reflect more of what is happening in the real world with greater consistency. Despite the inadequate data set used, CHANGE appears to be more efficient and better able to provide a sound basis for development planning and policy analysis than the more informal methods previously used.

9
THE RESOURCE ALLOCATION AND PRODUCTION COMPONENT OF THE KOREAN AGRICULTURAL SECTOR MODEL

Hartwig de Haen
Friedrich Bauersachs

PROBLEMS AND POLICY ISSUES TO BE ANALYZED

During the last 15 years, the Korean agricultural production system has experienced drastic changes with respect to kinds, levels, and composition of resources used, resource productivities, and levels and composition of output. This may indicate that Korean farms have continued their transition from traditional subsistence production to a commercialized market orientation. Considering the various interactions between agriculture and the rest of the economy, it seems safe to state that this structural change was both cause and result of a considerable national economic growth. In fact, the underlying hypothesis on which current economic policies as well as modeling and planning efforts in Korea are based is that an intensive reallocation of resources within agriculture and changes in the production structure will continue in the future in spite of the remarkable change that has already taken place in the past. Any planning and policy analysis will have to take this into account.

Table 3 provides some empirical information on the dynamics of resource use and production in the past. Although the growth rate of agricultural GNP is still lagging behind the total economic growth rate, the ratio between the two growth rates is rising and has doubled during the last ten years. (Between 1972 and 1975 the growth rate of agricultural GNP was 4.9 per cent, compared to 9.4 per cent of the total economy average, and the agricultural share of the GNP of the total economy steadily declined from 28 to 24 per cent.) This was possible in spite of the fact that during the second half of the 14-year period between 1960 and 1974, agricultural labor and land resources declined in absolute terms, whereas both had been growing before. Some of this resource withdrawal has been offset by increased fertilizer application and mechanization. However, the growth of production was still not high enough to meet the growing demand. The figures in Table 3 indicate that the import-export deficit for agricultural commodities has been widening in relative and in absolute terms. Moreover, in spite of increases in rice yield and price support policies, the growth rate of food grain production has declined below that of population. Also, there is an increasing requirement for concentrates to feed the rapidly growing livestock herd. The slow rate of increase in grain production may partially be due to a rise in areas of nongrain commodities, e.g., vegetables. However, other important reasons may include the decreasing cultivated area, a reduced labor force, and, possibly, changes in age and sex structure of the labor force.

It is expected that the farm population will decline further to about 11.5 to 12 million in 1985 and that the cultivated area will be reduced for urban and industrial use by another 0.2 million hectares (10 per cent) by 1985. Hence, a rise in agricultural production, stated as the most important goal of agricultural policy, will require a continuation of this process of structural change. If a continuation of national income growth and an increasing food demand are taken into account, policies aiming on the one side at higher self-sufficiency in food and on the other at world market scarcities might even increase the pressure on agriculture to reallocate resources and to increase the rate at which technical change is adopted.

Moreover, income elasticities for various food items indicate a rising proportion of protein in the diet or, more generally stated, of livestock in the overall production structure. In particular, dairy and beef production will most likely continue to expand more than proportionally and, hence, require development and intensification of pasture land, importation of feed grain, and capital investment in herd expansion and buildings. Increasing livestock production will mean more competition between food and feed grain production. It may also accelerate the rate of mechanization by further replacing dual-purpose draft cattle with more specialized beef cattle. Alternatively, Korea may choose to rely on imports of these commodities, particularly beef, to meet rising demands. This list of examples for adjustment and structural change in resource allocation and production could be easily extended to other areas, such as irrigation and water development, to enable fertilizer intensification and rising double-cropping ratios, etc. However, it will suffice to indicate the importance of analyzing this process by means of a model component that is both sufficiently detailed and dynamic.

TABLE 3
Selected Indicators of Korea's
Resource Use and Production, 1960-74

Indicator	Period: 1960[a] 1961[b] 1962[c] 1963[d]	Period: 1967	Period: 1974	Average Yearly Growth Rates (Percentage): (1960 1961 1962)-1967	Average Yearly Growth Rates (Percentage): 1967-1974
Total population (millions)	24.99[a]	29.54	33.46	2.4	1.8
Farm population (millions)	14.56[a]	16.08	13.46	1.4	−2.5
Share of farm population (%)	58.0[a]	54.40	40.0	−0.9	−4.3
Share of agricultural GNP (%)	43.5[c]	37.8	24.9	−2.8	−5.9
GNP growth rate agr./economy	−5.8/3.1	−5.0/7.8	5.7/8.6	...	...
Area of cultivated land (millions of hectares)	2.03[a]	2.31	2.24	1.8	−0.5
Fertilizer use (thousands of metric tons)	308.5[b]	486.5	836.7	5.6	8.1
(metric tons/hectare)	0.15[b]	0.21	0.37	5.6	8.1
Number of tillers (thousands)	30.0[b]	3,819.0	60,056.0	80.8	39.4
Total food grain production (millions of metric tons)	5.3[a]	6.8	7.3	3.7	0.9
Vegetable production (millions of metric tons)	1.2[a]	1.9	3.0	6.9	6.7
Cocoon production (thousands of metric tons)	...	10,903.0	30,980.0	16.9	17.4
Korean cattle (thousands of head)	1,010.0[a]	1,243.0	1,778.0	3.0	5.1
Dairy cattle (thousands of head)	.8[a]	10.4	73.2	35.5	27.9
Hogs (thousands of head)	1,397.0[a]	1,296.0	1,818.0	−1.1	4.8
Value of agricultural imports/exports ratio	2.67[d]	1.98	2.63	...	...

Yields (metric tons/hectare)	1957 to 1960	1964 to 1967	1971 to 1974	1957/1960 to 1964/1967	1964/1967 to 1971/1974
Total food grain	1.91	2.28	2.66	2.5	2.2
Paddy rice	2.78	3.11	3.50	1.6	1.7
Barley and wheat	1.56	1.87	2.16	2.6	2.0
Sweet potatoes	13.70	17.50	17.60	3.5	...
Soybeans	0.52	0.59	0.87	1.8	5.5
Chinese cabbage	...	12.60	12.70	...	...

Sources: Yearbooks of Agriculture and Forestry Statistics, Seoul, 1971 and 1975. Major Statistics of Korean Economy 1975, EPB, Seoul, 1975.

Some of the basic questions that the farm resource allocation and production component (RAP) is designed to approach can be summarized as follows:

1. *Explanation and basic projection*. Given initial resource endowments, production patterns, projected rates of change of land and labor inputs, technology sets, and historical prices, how will farmers allocate their productive resources to various enterprises and how will they finance production and investment? What will be their supply responses?
2. *Sensitivity analysis of exogenous factors*. How would alternative assumptions with respect to exogenous variables and key model parameters — e.g., alternative off-farm migration rates, rates of technical change, or wage-interest ratios — affect the expected level and time profile of technology, input use, production, and farm income?
3. *Policy analysis*. What will be the impact of alternative agricultural policies — namely price policies, import quotas, or input subsidies — on the performance indicators mentioned above?

MODELING FARM RESOURCE ALLOCATION WITHIN AN INTERDEPENDENT SYSTEM: BOUNDARIES OF THE COMPONENT

Basically, RAP is designed to model the activities of farm households as behavioral decision units. This provides a general definition of component boundaries to the environment, the latter being represented by the factor and product markets. Population dynamics result from demographic characteristics and off-farm employment opportunities and by policy measures and exogenous factors affecting resource endowment and resource productivities, as well as institutional considerations. The mainstreams of component interaction within the overall model have been demonstrated in earlier chapters.

Figure 27 indicates the major linkages of RAP with the rest of KASM, including policy inputs, exogenous variables, and component-specific output variables. Seasonal labor supply, producer prices,[1] and yield levels, with the corresponding input application rates, are major inputs into RAP from other KASM components. Other inputs are land, by three different categories; prices of variable inputs; interest and wage rates; technical coefficients with respect to mechanization and labor use; double-cropping ratios; and so on. Policy inputs include input price subsidies, credit, and land development. Outputs to other KASM components are food production levels by commodity, agricultural farm income, and feed grain imports. Other outputs include input use, technology levels, shadow prices of fixed resources, capital stock, savings, and indebtedness.

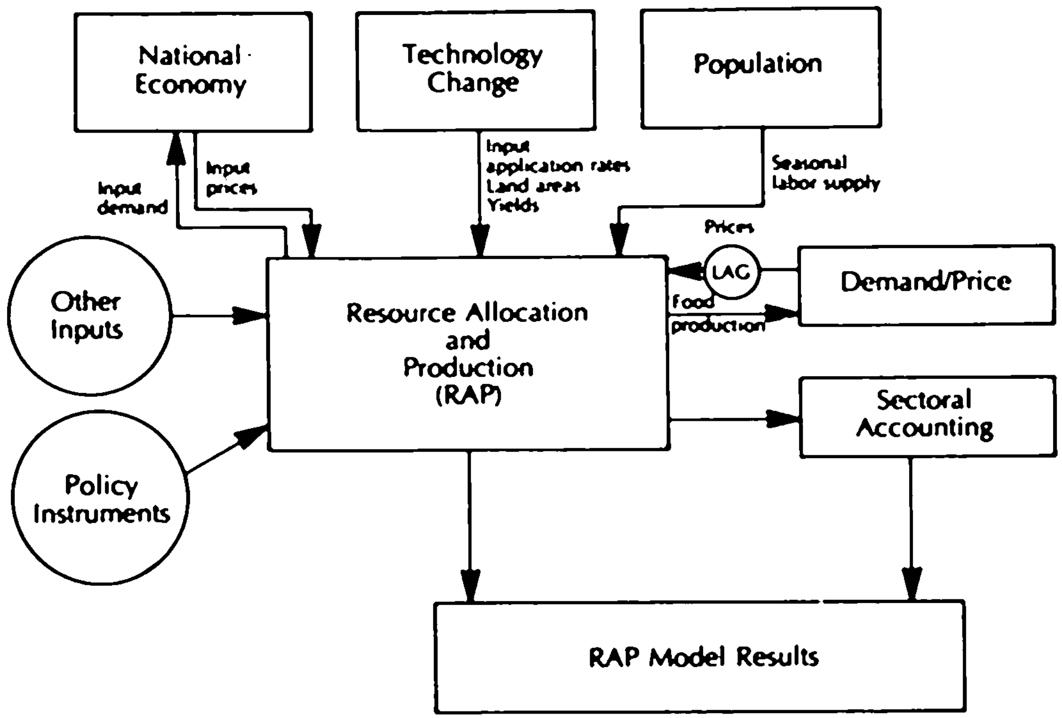


FIG. 27. Major linkages between the resource allocation and production component and the rest of the Korean agricultural sector model.

INTERNAL STRUCTURE OF *RAP*

Basically, farmers' resource allocation decisions are modeled in a sequence of linear programming models dynamically linked with the overall KASM. This component of KASM can be described as block recursive, with one block containing a set of inequalities and a selection rule (objective function) representing a behavioral assumption as to how farmers choose among alternative actions in any given period. This is an attempt to represent the adaptive behavior of the system as a function of two equally important feedback mechanisms: internal feedback within the farmers' decision framework and external feedback from markets, demographic conditions, and policy reactions. Figure 28 contains the internal structure of the component. Basically, it consists of a farm resource allocation subcomponent (FRESAL) and a production accounting subcomponent (PRDAC). The resource allocation subcomponent contains a one-period linear programming model allocating given resources to production, investment, and financing activities; an internal feedback relating previous actions to current decisions; and an external feedback establishing the interactions with the other components. The production accounting subcomponent aggregates the detailed programming results and computes production levels for the 12 crop and the 5 livestock commodities. Moreover, this subcomponent computes other variables resulting from resource allocation and production; namely, income and savings and input requirements, such as fertilizer, fuel, chemicals, feed grain, etc. Following is a more detailed description of the resource allocation subcomponent (FRESAL), divided into (1) the allocation of resources in any given period and (2) the dynamic feedback linking the periodic decisions.

Resource Allocation

A farm in Korea is typically small and multienterprise, producing annual crops on paddyland and upland, perennials, and, to an increasing extent, livestock products. Since the cultivated cropland is essentially limited to three hectares per farm, livestock production provides a major source for additions to the income capacity of the farms. The multienterprise character of the Korean farms and the effectiveness of various common constraints at the farm level make it difficult to model resource allocation separately for individual commodities. Moreover, the expected further technical progress, changes in consumer preferences, and structural changes within the sector do not conform to simple trend extrapolations. Because of these considerations the decision was made to model explicitly farmers' decision processes with respect to resource allocation and production. The assumed decision rule, supported by various case studies, may be defined as cautious optimizing. According to this rule, farmers try to maximize expected profits subject

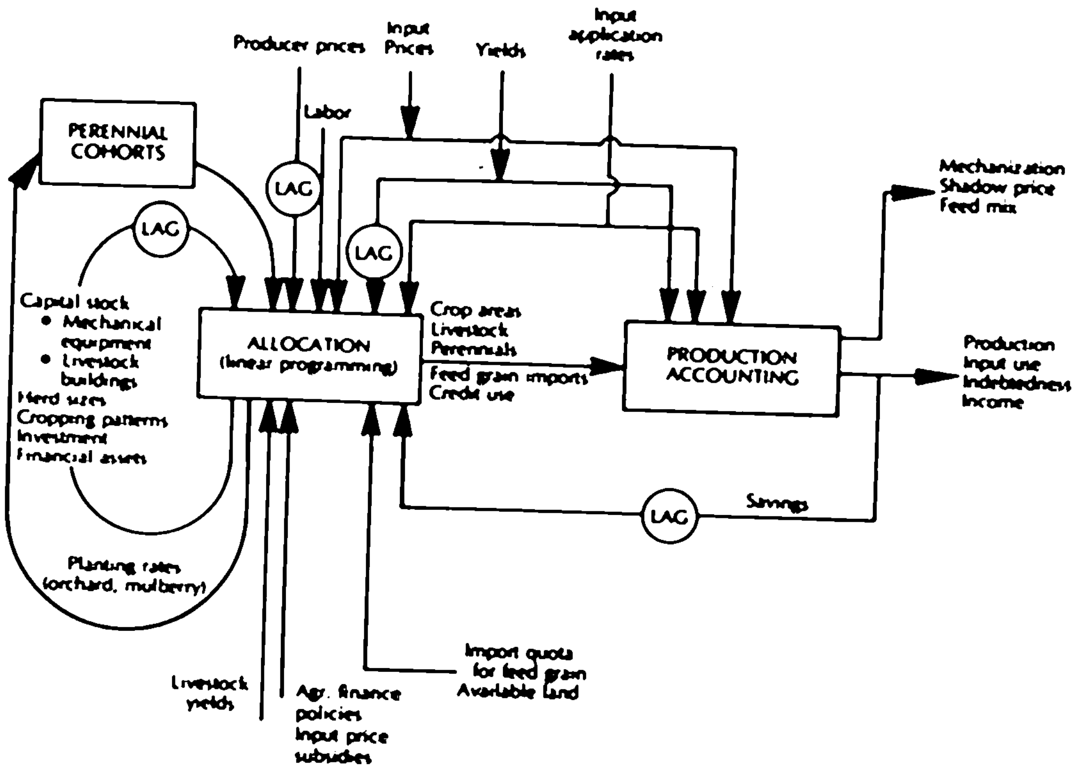


FIG. 28. Internal structure of the resource allocation and production component.

to technical, institutional, and behavioral restrictions, provided that the possibility of ruin (income less than subsistence level) is negligibly small. The allocation decisions resulting from this rule are subject to change in any new period, depending on any deviations between expectations and realizations affected by the environment. Mathematically, the allocation decisions are simulated by a recursive linear programming model,[2] which, for any given period, has the following form:

$$\pi_t^* = \max_{X_t} Z_t \cdot X_t$$

such that $\mathbf{A}_t\ \mathbf{X}_t \leq \mathbf{Y}_t$

$$\mathbf{X}_t \geq 0$$

where π^* is the expected "optimal" (or rather, "satisfying") value of the objective function, **X** is the vector of activity levels, **Z** is the vector of expected returns per activity unit, **A** is the matrix of technical coefficients, and **Y** is the vector of physical, behavioral, or institutional constraints.

The dynamic internal and external feedback is established through three sets of linkage functions — namely, an objective function, a constraint vector, and input-output matrix operators:

$$\mathbf{z}_t = z\left(\mathbf{x}_{t-1}^*, \ldots, \mathbf{x}_{t-p}^*;\ \mathbf{r}_{t-1}^*, \ldots, \mathbf{r}_{t-p}^*;\ \mathbf{u}_{t-1}, \ldots, \mathbf{u}_{t-p};\ \mathbf{v}_t\right)$$

$$\mathbf{Y}_t = y\left(\mathbf{Y}_0;\ \mathbf{x}_{t-1}^*, \ldots, \mathbf{x}_{t-p}^*;\ \mathbf{r}_{t-1}^*, \ldots, \mathbf{r}_{t-p}^*, \mathbf{u}_{t-1}, \ldots, \mathbf{u}_{t-p};\ \mathbf{v}_t\right)$$

$$\mathbf{A}_t = A\left(\mathbf{x}_{t-1}^*, \ldots, \mathbf{x}_{t-p}^*;\ \mathbf{r}_{t-1}^*, \ldots, \mathbf{r}_{t-p}^*;\ \mathbf{u}_{t-1}, \ldots, \mathbf{u}_{t-p};\ \mathbf{v}_t\right)$$

where * indicates optimality, **r** is the vector of dual values (shadow prices of constraints), **u** is the vector of KASM output variables — i.e., variables that are exogenous to FRESAL but endogenous to other components, and **v** is the vector of exogenous variables.

The matrix **A** is basically block diagonal, with one block for each region and additional national constraints as indicated in Figure 29.

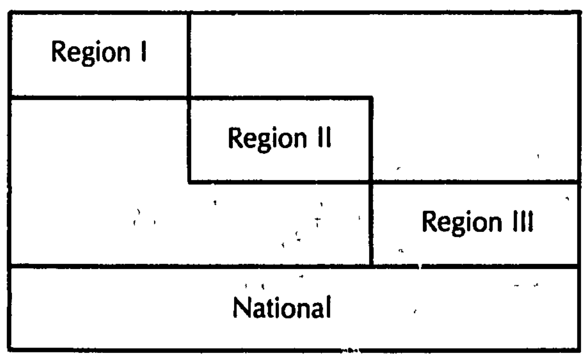


FIG. 29. Regional disaggregation of the coefficient matrix in FRESAL.

The current version of the model does not use the potential for the regional breakdown, mainly in order to increase computational efficiency, but also because of a lack of sufficiently accurate regional data. The main structure of the yearly allocation model on the national level[3] is sketched in Figure 30.

The model activities are (1) production of various annual crops, including forage and pasture management, disaggregated by types of technology; (2) perennial production and new planting; (3) livestock production; (4) temporary upland use of paddyland; (5) investment in farm machinery, in buildings, and in livestock expansion; (6) feed grain imports; (7) financing, including savings and loans; (8) seasonal, nonagricultural employment or additional leisure time; and (9) various transfer activities.

The technology may either be traditional (at the beginning of the 1970s, Korea had basically a hand-and-ox technology) or mechanized with a 10-horsepower tiller that includes the necessary attachments. In the case of rice, a third technology that includes a semiautomatic rice transplanter is possible. So far, there is only limited experience with tiller cultivation on paddyland and the effects of better and deeper cultivation. The model assumes incremental yield increases on mechanized areas between 0 and 5 per cent.[4]

The financing activities establish a step supply function of financial sources, originating with rising interest rates from (1) own capital, (2) long-term investment loan, (3) short-term loan for investment in working capital from either financial institutions, or (4) private sources.

The constraints of the model include the acreage of paddyland, summer upland, and winter upland (double cropping); an additional restriction on paddy temporarily used for upland crops; and the acreage of mature orchards and mulberry fields. Furthermore, there are limitations on human labor, draft cattle, and machinery during the two most important peak seasons (June and October) and an additional labor constraint for the rest of the year. Livestock herd sizes (Korean cattle, dairy, hog, poultry) cannot exceed the number of head raised in the past plus births in excess of replacement. (In the current version of the model poultry production is introduced exogenously.) A capital stock constraint for physical capital other than machinery calls for investment if livestock, buildings, or working capital are expanded. Moreover, there are various feed balances and one restriction on feed grain import in the model. Four constraints are relevant for the financial sector: namely, a constraint on liquid assets counting accumulated savings — it can be used for short-term financing of production and long-term investment; a constraint on investment capital for machinery investment and livestock expansion; and two minimum,

	Constraints \ Activities	Annual Crop Production: Traditional	Annual Crop Production: Modern	Roughage Production: Traditional	Roughage Production: Modern	Animal Production: Cattle (Draft, Dairy, Beef)	Animal Production: Hogs/Poultry	Perennials: Planting	Perennials: Production	Investment and Financing: Bank Account	Investment and Financing: Investment	Investment and Financing: Loans	Admissible Loss	Internal Transfers: Paddy to Upland	Internal Transfers: Feed or Sale	Internal Transfers: Alternative Labor Use	Imports
Land	Paddy, summer upland, winter upland	x	x	x	x			x						x			
	Pasture			x	x												
	Perennials								x								
Labor	Human labor (by seasons)	x	x	x	x	x	x	x	x							x	
	Draft cattle (by seasons)	x		x		x					x						
	Machinery (by seasons)		x		x												
Capital	Liquid Assets: Total (savings, working cap.)	x	x	x	x	x	x	x	x	x	x	x					x
	Liquid Assets: Investment cap										x	x					
	Farm capital in buildings and livestock					x	x				x						
	Internal credit rationing	x	x	x	x	x	x	x	x	x	x	x					
Risk and Behavioral Constraints	Minimum income	x	x	x	x	x	x	x	x	x			x				
	Risk constraint	x	x										x				
	Flexibility of production and herd expansion	x	x	x	x	x	x	x		x							
	Adoption of technology							x									
Physical Balances	Feed grain balance	x	x												x		
	Supply/demand of feed			x	x	x	x								x		x
	Multi-cropping land	x	x											x			
Sectoral Constraints Policy Instruments	Feed grain import Quotas																x

FIG. 30. Activities and constraints of FRESAL.

self-financing constraints on investment in working capital and long-term capital stock, respectively.

The model reflects suboptimal or cautious behavior of farmers by incorporating a mechanism of risk aversion and restricted flexibility and, thus, establishing a lexicographic preference ordering. Maximization of expected profits is the allocation principle only insofar as two safety conditions are fulfilled:

1. The possibility of ruin resulting from a certain production pattern — i.e., of receiving an income that does not cover unavoidable expenses — lies below a given probability threshold
2. Year-to-year changes in cropping patterns and livestock production stay within certain flexibility constraints; i.e., do not exceed maximum deviations observed during a ten-year historical period

The risk-aversion approach is based on the assumption that farmers try to diversify their production patterns in such a way that the potential loss PL_j expected under unfavorable weather and market conditions for any group J_l of production enterprises is not likely to exceed a fraction $1/k_l$ of the total admissible loss (activity *LOSS*).[5] The total permissible loss is the difference between the expected income from production $\sum_j z_j \cdot x_j$ and unavoidable expenses (= minimum income "*MINI*") for subsistence consumption, debt service, taxes, etc.

$$LOSS = \sum_{j=1}^{n} z_j x_j - MINI$$

$$\sum_{j \in J_l} PL_j x_j \leq \frac{1}{k_l} LOSS$$

Since this risk-aversion mechanism will only account mainly for the effects of yield and price fluctuations and not include the many other determinants of uncertainty and risk, a set of upper and lower bounds ($\bar{x}$ and $\underline{x}$) is introduced to avoid unreasonable fluctuations that cannot be explained by the aforementioned mechanism:

$$\underline{x}_j \leq x_j \leq \bar{x}_j$$

Generally, the risk constraint will only hold if the corresponding flexibility constraint is ineffective and vice versa.

Similar to the flexibility constraints for production patterns, net investment in new machinery (tillers plus attachments and rice transplanters) is restricted and cannot exceed a certain proportion of the current stock of machines existing in any given year. This reflects the adoption behavior of farmers during the transition process, where learning and diffusion of innovations are accelerated as the number of previous adopters increases.

Internal Feedback, External Feedback, and Exogenous Variables: The Dynamics of Resource Allocation

In order to account for the dynamic properties of the sectoral adjustment and growth process, dynamic feedback operators and linkages are defined that relate the values of the objective function, matrix coefficients, and constraints on preceding solutions of the programming model to variables being computed in other parts of KASM and to exogenously projected variables. Following is a brief review of feedback linkages for the objective function and the constraint vector. A formal representation follows in an appendix.

The objective function coefficients represent farmers' anticipations of future costs and returns. Profit expectations for field crops are a function of exponentially lagged producer prices, one-period lags of yields, and the corresponding variable costs. For livestock production the objective function coefficients are equal to the previous yearly average of net returns during the mature production phase, minus proportional replacement costs, plus proportional salvage returns.

Investment decisions depend on the expected marginal value product and marginal costs. In the case of farm machinery, buildings, and livestock investment, the marginal value product is computed endogenously through production activities using the respective capital; hence, the objective coefficient includes costs for depreciation only. For investment in perennials (planting of orchards or mulberry fields), where yields are not immediately available, decisions to plant are based on the marginal value product imputed to the existing mature field in the previous year.

Finally, the objective function coefficients of all other activities, namely feed imports and activities to establish intersectoral linkages on the credit and labor markets, are determined exogenously. They refer to import prices, interest rates, and opportunity costs of labor.

The constraints of the programming model indicate the state of the system at the beginning of a period. Whereas the total paddy area, as well as summer upland, is projected exogenously (in CHANGE), upland for annual crops is a function of endogenously computed areas, along with perennial crops.[6] Winter upland depends on the double-cropping potential of paddyland and upland.

Seasonal labor constraints are determined by the seasonal size of the agricultural labor force projected by the population component (POPMIG) and by the labor requirements of the new perennials not yet in production.

In order to account for learning effects that are due to mechanization, general agricultural research, labor scarcity, and rising educational levels, the efficiency of labor use is assumed to grow within certain limits. This is reflected in the model by gradually increasing the working time equivalent.

A vintage approach is used to simulate the capacity development of machinery, namely power tillers plus attachments for land cultivation and rice transplanters. The current total capacity per season depends on previous investments, and the unit capacity is determined by a depreciation schedule. Other capital stock is simply a function of initial conditions and net additions through investment. This includes mainly indigenous capital, such as livestock and buildings.

Technically maximum herd sizes of livestock (measured in female breeding units) are computed as a function of the actual herd in the previous year, of the potential net additions from the young female herd, and of livestock imports determined by policy. If the maximum herd size is not used, the difference is assumed to be slaughtered.

Pasture land, although in most cases collectively used by the villages, night become an important limiting factor for cattle and dairy herd expanion and is treated as a farm resource in the model. The capacity will depend on the rate of reforestation and public investment in upland devel-pment in general. It is projected exogenously [18].

A further set of constraints reflects the financial capacity of the farms, namely the availability of liquid assets, investment capital, and credit. Liquid assets are available to finance the current production (working capital), to increase the capacity of other farm assets (investment in nachinery, buildings, and livestock), and can alternatively be deposited in ank accounts. At the beginning of any period, liquid assets are computed s the sum of the previous working capital, minus repayment of short-term pans, plus savings out of previous income and bank accounts. The disposble income is defined as the actual agricultural value added, plus nonagcultural income, minus taxes, interest, and principle.

Both short-term bank loans and long-term loans can be limited xogenously. The current version, however, contains an internal rationing nechanism. The credits cannot exceed a certain proportion of the working apital and investments in new capital stock respectively. The level of the ninimum income to be covered by returns from the farming sector equals a ninimum subsistence requirement (a proportion of the previous average come allocated to consumption) plus unavoidable expenses for debt rvice, interest payments, and taxes.

Flexibility and adoption constraints for production and investment atterns are a function of the previous year's optimal level of the respective ecision variables and of the previous state of the system. For investment in echanized technology, an adoption constraint is introduced to avoid nrealistically drastic increases in the stock of machinery, an assumption at seems particularly important in the current process of transition from aditional hand labor and draft cattle to mechanized technology.

Time-varying technical coefficients of the programming model, namely yields and feed requirements, are either projected exogenously or are derived from the crop technology change component (CHANGE). Yield projections are consistent with assumed fertilizer application rates for crop activities and feed input levels for livestock activities.

Production Accounting

Once the allocation of resources to various production activities is projected for any given year, output levels of 12 crop and 5 livestock commodities can be computed by simply multiplying activity levels by the respective actual yield levels. Similarly, the actual demand for various inputs (fertilizer, chemicals, fuel, or concentrates) can be computed by enterprise and by kind of input. Actual yields and the corresponding unit requirements of inputs are projected either exogenously or endogenously in the CHANGE component. Total output by commodity, both gross and net, after subtracting farm losses, and total input by kind result from simple aggregation. They can be checked for consistency with national and sectoral accounts. Moreover, they are inputs to the national economy component (NECON). Multiplied by the respective commodity prices (from DEMAND) and by input prices, respectively, they yield the "value of output" and "value of inputs" needed to compute income and other related performance variables.

DATA REQUIREMENTS FOR *RAP*

Following is a brief discussion of data needs for the farm resource allocation and production component. Inputs from other KASM components are excluded. For the remaining data, a distinction will be made among initial conditions, constant parameters, and time-varying parameters or exogenous variables.

Initial Conditions

Initial conditions are required for the entire constraint vector of the annual allocation model. They include (1) land constraints, derived from official statistics published by the Ministry of Agriculture and Fisheries (MAF); (2) seasonal capacities for human labor (derived from POPMIG) and for draft cattle and machinery, both from MAF statistics; (3) liquid assets, farm capital, and income, derived from the Farm Household Survey and sectoral accounting data; and (4) flexibility constraints for cropping patterns and livestock production, derived from MAF statistics on historical cropping areas and production levels.

Constant Parameters

RAP uses a wide range of parameters related to production technology, input productivities, prices, and behavioral assumptions. Both positive and normative concepts are involved, which may explain some of the difficulties in obtaining real-world observations for these parameters. Almost none of them is constant in the real world. However, some of them are assumed constant because of a lack of data. Constant in time are mainly (1) parameters indicating the composition of some crop aggregates and intercropping rates in perennial fields, both derived from MAF statistics; (2) by-product yields (straw, vegetable leaves, bran) of crops; (3) mechanization costs and unit labor requirements for given technology levels, derived from a report on farm mechanization in Korea [48] and survey data provided by the Farm Management Section at the National Agricultural Economics Research Institute (NAERI); (4) application levels of various livestock inputs — e.g., equipment, veterinary; (5) standard deviations of yields and prices for field crops; (6) flexibility coefficients for production patterns, derived from either historical time series or off-line trend projections (currently, off-line trends are projected for egg and chicken production); and (7) maturation delays of perennials.

Time-Varying Parameters

Exogenous variables and time-varying parameters are by definition based on off-line projections and, hence, establish the numerical conditions for the model projections. Such exogenous projections include (1) yields of annual and perennial crops, insofar as they are not provided by CHANGE, and the related variable input levels; (2) livestock yields, feed requirements, and fertility rates, derived from a report on feed supply and use of livestock production [110] and farm management surveys done by NAERI; and (3) prices for variable inputs (not provided by NECON), interest rates, and opportunity costs of labor, indicating marginal values of leisure or additional off-farm employment opportunities.

BASIC MODEL RESULTS AND VALIDATION

This section contains a sample of model results for resource allocation and production. Base-run projections (1975–85) are based on fixed price policies for rice, barley, wheat, silk cocoons, and tobacco. Other prices are determined in the market within given bounds. To obtain the important feedback relationships with prices, RAP was run with DEMAND for these tests. The major purpose of this section is not to arrive at particular policy conclusions, but rather to demonstrate the model's potential to support policy analyses by providing information about the dynamics and consistency of structural change, as well as about resource scarcities and productivities resulting from alternative policy measures and parameter assumptions.

The presentation of results concentrates on the most important trends and is almost entirely graphical. Where possible, it includes a nine-year historical reference period, indicating the observed patterns of change and enabling a visual time series comparison to be made for four years. Running the model during a longer historical reference period was not possible because of a lack of sufficiently accurate time series data. The overall validation and verification has been a part of component development from the beginning and cannot be discussed here in its full complexity. It included the confrontation of the logical model structure, of data assumptions, and the plausibility of results with the experience and knowledge of experts in relevant Korean government agencies. Formal time series comparisons, although necessary and useful, cannot be substituted for this process not only because it is very difficult to determine the model's degree of freedom (to deviate from observed patterns of change), but also because some of the policies and technical changes did not exist in the past.

The discussion of basic model results will be divided into the following categories: (1) trends in production patterns; (2) factor productivities, income, and income composition; and (3) interpretation of model results and experiences with the general approach.

Trends in Production Patterns

Generally the model explains the past trends in land allocation fairly well, with the exception of pulses and potatoes (Fig. 31). At the given prices for the historical time period (1971–74), the areas with barley (plus wheat) and pulses (plus other grains) continue to decline, whereas vegetables and industrial crops increase in acreage. Potatoes, in spite of a steep price increase, decline in area. The area in rice expands at a slightly increasing upper bound in the model.

The projection from 1975 to 1985 is based on a specific set of price policy assumptions, mainly fixed high prices for rice, barley, and wheat. The main result of such a policy would be, after a time delay of one to two years, a reversal of the decline in barley area — barley substituting for industrial crops and tobacco and also potatoes, which, under market conditions, would suffer a steady price decline to a lower bound. The area in vegetables would continue to level off around 240,000 hectares. At the given low price elasticities of demand and the competitive position of vegetables implicit in the production data, the results demonstrate very clearly a cyclical dynamic behavior, with a two-period lag between prices and production response. Figure 31 also contains results for an alternative set of price policies, differing from the previous set by the assumption that rice, barley, and wheat prices are determined in the market. The result is a lower level of rice and barley prices; a slower increase of barley and wheat areas, with some unused double-cropping land; and, not shown in the figure, a substitution of feed grain imports with domestically produced grain. Production of rice and other crops is mostly unaffected, in spite of much lower rice prices.

Certainly, these results cannot be fully interpreted unless the effectiveness of the constraints and their respective shadow prices are taken into account. In fact, the dual solution indicates that for this run, for example, barley and wheat are generally the "residual users" of double-cropping land, since most competing crops are either bounded from above or below. More details on model interpretation will be discussed under the next two subheadings.

Figure 32 demonstrates some results on livestock production. Egg and poultry meat production are exogenously projected, since their competition with other agricultural products is very limited and, at the chosen level of aggregation of the model, difficult to specify realistically. Poultry production is mainly determined by the ratio of product to concentrate prices, the latter depending very much on world market prices, which are difficult to project. Earlier attempts to explain poultry production endogenously resulted, therefore, in fluctuations that seemed clearly unrealistic. It is assumed that the number of layers and broilers grow at the same rate. The higher growth of egg output results from the assumed growth rate of egg yields per hen.

The model explains reasonably well the past development trends for dairy, beef, and hogs. The projections to 1985 show a rapid increase in milk production and a more modest expansion of pork and beef production, the latter fluctuating considerably around the trend. The prices, mostly determined in the market, remain relatively stable in spite of the considerable output growth, which seems a realistic reflection of the high income elasticities of demand for livestock products. The dual solution indicates that dairy production is growing along the maximal natural expansion path. At the assumed rate of yield increase, dairy production remains profitable even at declining milk prices. Further research will be necessary to provide evidence whether this result is realistic or whether other cost items, more rapid declines in the income elasticity of demand, as well as limitations in the availability of high-quality roughage might lead to a decline in the growth rate of dairy production. Beef and hog production would, according to the model results, respond more sensitively to variations of prices and feed costs, beef being mainly Korean cattle that provide animal labor at the same time.

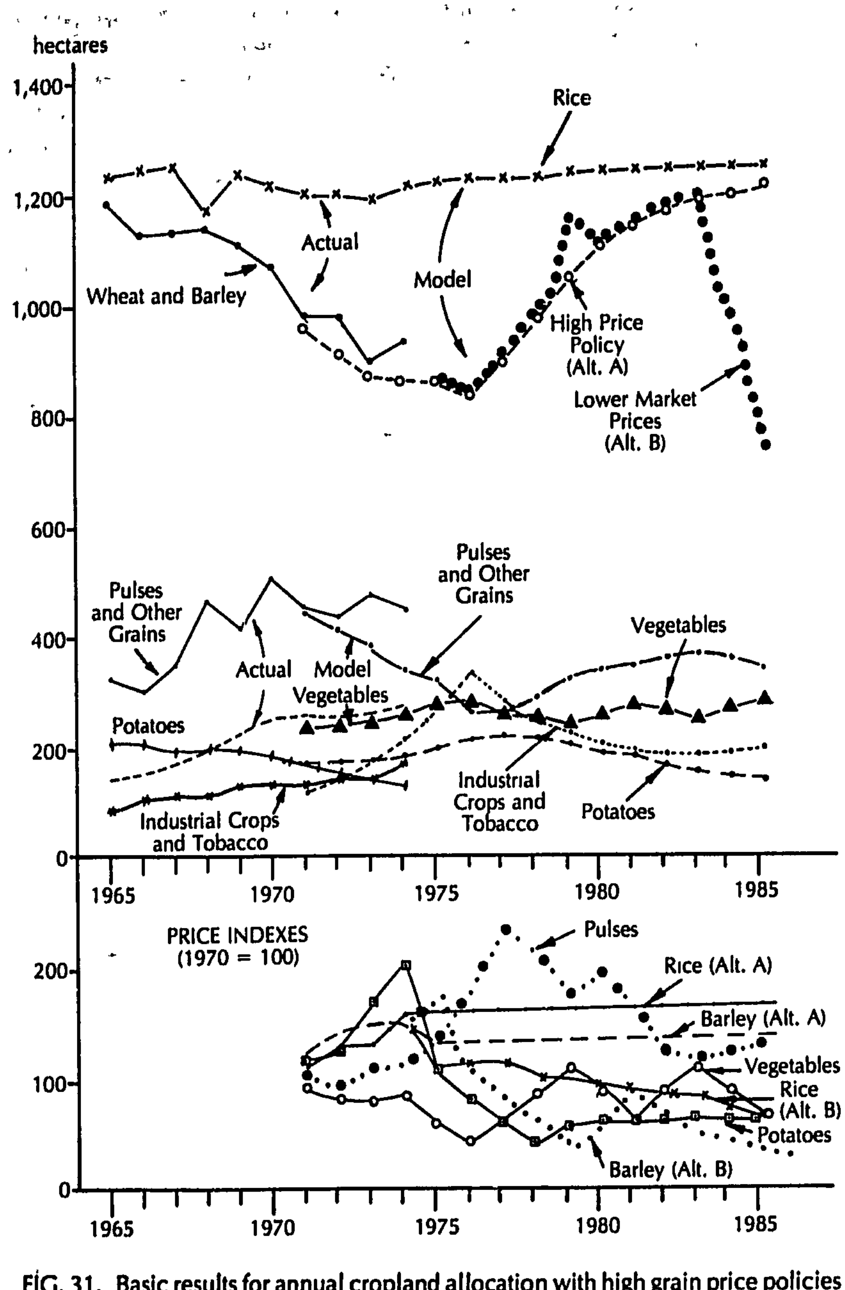


FIG. 31. Basic results for annual cropland allocation with high grain price policies for rice, barley, and wheat (Alternative A) and major deviations for a market price alternative (Alternative B).

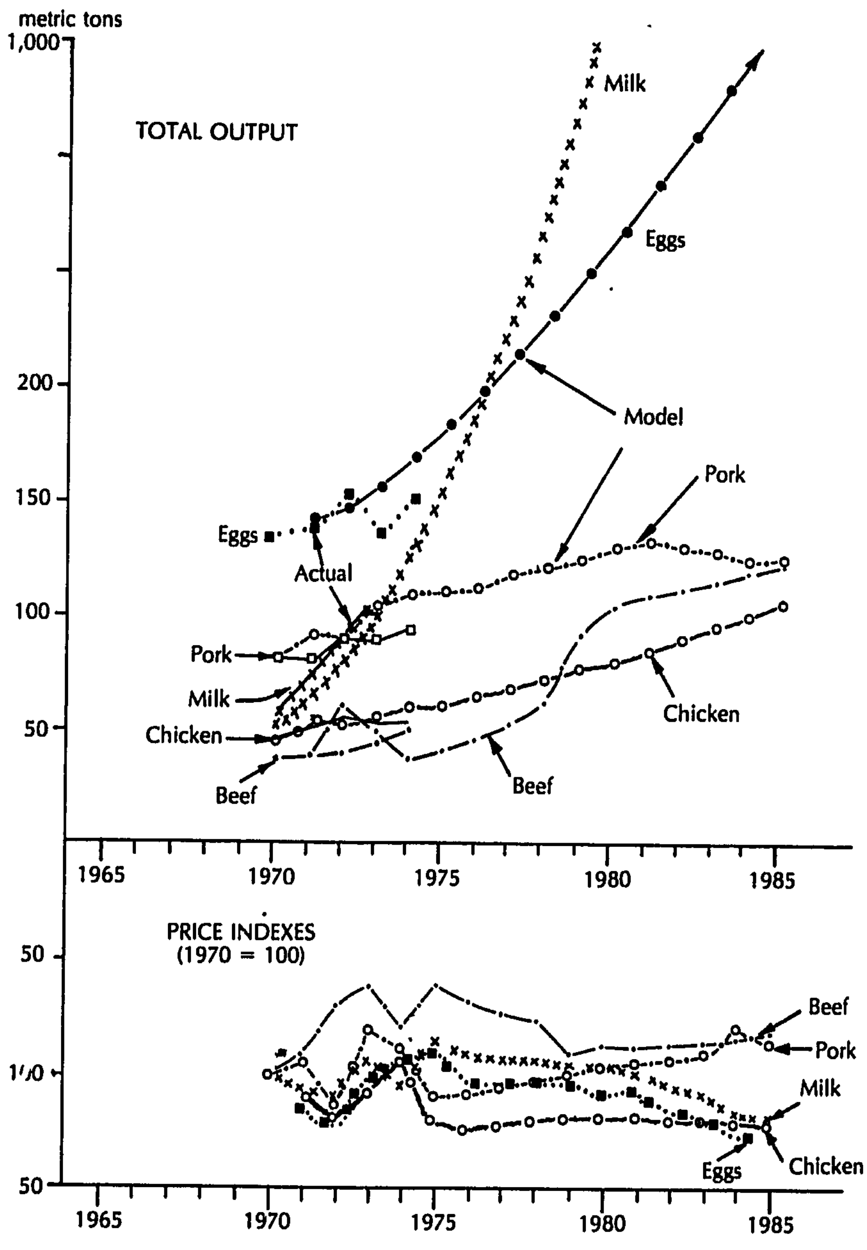


FIG. 32. Basic results for livestock production (Alternative A).

Factor Productivities, Income, and Income Composition

Certainly the model is not yet sufficiently tested to allow final conclusions to be drawn concerning the future income of Korean agriculture and the contribution of various resources. However, some basic insights can be gained from the results, and key areas for further research and testing can be indicated.

Although the real growth rate of agricultural value added is overestimated for the reference period 1971–75 (8.7 per cent compared to 4.5 per cent), the base-run projection from 1975 to 1985 of 4.5 per cent seems plausible and comes close to official plan figures. The overestimation may be caused by incorrect specification of initial conditions.

Table 4 contains some information concerning the level of the agricultural value added (at 1970 prices), its distribution by commodity groups,

TABLE 4
Projected Agricultural Income and Resource Productivities

Performance Variables	1971	1972	1975	1980	1985
Agricultural Value Added.					
Billion won	697	776	989	1,302	1,551
Index (1971 ≒ 100)	100	111	142	187	222
Distribution by Commodities					
Crops (percentage)	84.4	84.7	83.5	78.5	76.5
Livestock (percentage)	12.2	12.2	14.0	19.7	27.0
Residual (percentage)	3.4	3.0	2.4	1.8	1.5
Contribution of Various Resources (in percentages)					
Land (paddy, annual, and perennial)	68.9	50.8	56.8	53.6	57.1
Labor	43.3	39.3	33.4	30.9	31.7
Capital (livestock, machinery, liquid assets)	6.3	2.3	1.6	7.3	10.1
Crop rotation, behavioral and technical constraints	−18.5	7.5	8.1	8.2	1.1
Selected Shadow Prices					
Paddy (th. won/ha)*	202	227	320	441	492
Upland (th. won/ha)*	28	29.2	36	40	49
Internal interest rate (percentage)	6.4	5.1	1.0	5.1	5.5

* Thousands of won/hectare.

and the relative contribution of various groups of resources. On the commodity side, the share of livestock products is gradually increasing and, thus, reflects the shifting preference of consumers with rising incomes. The factor income distribution is computed by taking the physical resource levels valued at their imputed marginal value productivities. These marginal-value productivities are derived under the behavioral assumptions of "cautious optimizing within bounds" and, hence, are not necessarily predictions of actual factor prices. However, they are useful in interpreting the relative importance of various groups of resources and in evaluating economic effects of marginal changes of resource levels. Except for the initial year, in which higher winter upland rents are imputed from vegetable production, the physical annual and perennial land input accounts for approximately 55 per cent of the total agricultural value added, indicating a relatively high rate of land scarcity. Labor is receiving a slightly decreasing share of 30 to 40 per cent, while the income share of capital, so far as it is included in the model — namely livestock, machinery, and liquid assets (working capital and savings) — is relatively small but increases from 2 to 10 per cent between 1972 and 1985. The low share during the initial four years is mainly caused by the very low real interest rates that were computed after accounting for the observed inflation rates. The remaining income would, under model conditions, be imputed to crop rotation, risk, and flexibility constraints and technical restrictions. Positive shares indicate upper-bound effects; negative shares measure lower-bound effects. Except for the first year, they do not contribute by more than 5 to 10 per cent; i.e., upper and lower bounds almost compensate each other.

Some concluding comments relate to the labor income. As mentioned in chapter 6, off-farm migration is projected exogenously in the current version of the model and is not affected by the agricultural income projected endogenously in this component. Since the projections with respect to migration are rather cautious and refer mainly to rural-urban migration, decision variables were introduced into the allocation subcomponent model that simulate additional seasonal off-farm employment, possibly favored by future rural development policies. The same variables might also be interpreted as leisure activities carried out whenever the marginal value product of labor falls below a certain limit. In fact, the base-run results indicate that the income share of labor is in most cases determined by these exogenous opportunity costs, except for the transplanting season in June, when labor is sometimes more scarce and priced higher than the external opportunity costs. As the figures in Table 5 indicate, the main decline in agricultural manpower is assumed to take place before 1975. After 1975 the projected rate of decline is very small (0.08 per cent) and might be overcompensated for by efficiency increases. Under the base-run assumptions (labor opportu-

TABLE 5
Mechanization and Rates of Labor Utilization at Low (Run A) and High (Run C) Opportunity Costs of Labor

	1971	1975	1980	1985
Agricultural manpower in peak seasons (thousands of man-equivalent units)	5,514	5,062	5,038	5,024
RUN A: Labor opportunity cost = 25 won/hour Growth rate = 4 per cent				
Used/Available Farm Labor				
Annual (percentages)	47	51	53	60
Peak seasons (percentages)	88	97	95	92
Number of Tillers	11.0	168.7	171.2	164.5
RUN C: Labor opportunity cost = 50 won/hour Growth rate = 8 per cent				
Used/Available Farm Labor				
Annual (percentages)	39	31	36	39
Peak seasons (percentages)	78	65	71	67
Number of Tillers	11.0	281.8	369.4	317.5

nity costs in 1970 at 25 won per hour, growth rate at 4 per cent per year), the average rate of on-farm use of this labor force would be only 50 to 60 per cent. Leisure or additional off-farm employment would make up 50 to 40 per cent. However, during the peak seasons the average rate would increase rapidly to almost 100 per cent, causing a substantial mechanization rate during the 1970s, which would later proceed much more slowly. Much higher rates of mechanization and of additional off-farm employment would result, if the opportunity costs were doubled in level and rate of change (Run C).

This discussion exemplifies the need for detailed interpretations of results that can lead to further model improvements. In order to explain migration endogenously, for example, a formal linkage between FRESAL and POPMIG might be considered.

Interpretation of Model Results and Experiences with the General Approach

In this section some comments will be made concerning the strength and the shortcomings of the general approach. Moreover, it will be argued that it is very important to interpret results comprehensively and that any separate use of partial results might lead to wrong conclusions and thus be dangerous. Finally, it will be shown how the model application could be adjusted gradually to the decision process within the planning unit.

Basically, it is true for any quantitative model that deviations between reality and model results can be due to false behavioral assumptions, an incorrect or incomplete specification of the system structure, aggregation errors, and/or false data. All of these sources of errors may be more or less relevant for RAP and should receive further attention. The behavioral assumption, according to which resource allocation results from cautious optimizing, is difficult to test but appeared to be consistent with impressions from many farm visits and the experiences of Korean farm management experts. These contacts led to several modifications of the model, examples being the assumption to use exponentially lagged price expectations and to introduce an explicit risk-aversion mechanism in order to explain better the observed diversification of cropping patterns. Actually, this procedure may highlight the general strength of the microeconomic approach, enabling good communication about data and assumptions with farmers, farm management experts, and even administrators.

Areas where the model structure might be incomplete or incorrect are related to (1) the various land categories, which should be distinguished according to existence of irrigation, rearrangement, or possibility for further double cropping; (2) mechanization, which might usefully be further disaggregated into different kinds and levels of technology; (3) liquidity and financing, examples of which for refinements of model structure might be seasonal liquidity and external credit rationing. All these additions would, in conjunction with data improvements, reduce the importance of exogenous flexibility constraints in explaining the diversification of production patterns which one observes in Korean agriculture. Whether or not an explicit modeling of subsistence behavior, which still exists in some parts of the farming sector, would also contribute to this explanation is another question needing further research.

Certainly a national model of the agricultural sector suffers from aggregation errors. Natural conditions are assumed to be homogeneous within the country, and labor is assumed to be completely mobile between farms. This may lead to overestimations of agricultural production potential and the flexibility of the system. If data were available, a regional disaggregation, as indicated earlier in this chapter, might reduce some of these aggregation errors. Furthermore, it would enable the planning unit to introduce regional policies and regional differences in opportunity costs of labor.

A further shortcoming of the current version of the model is its data base. Many cost items are not well known on a commodity or enterprise basis and will have to go through further consistency tests. This holds, for example, for production function data, mechanization costs, and labor requirements. Uncertainty exists also with respect to initial financial conditions, the farm capital requirements for activities not directly related to production as contained in the model (e.g., farm buildings, storage, irrigation), or propensities to save. Using the current data assumptions, the projected composition of field crops is very much determined by the gross income per hectare. Even after several revisions, the data indicate an extremely wide range of gross incomes between crops, resulting in a relatively small impact of labor requirements, mechanization costs, capital, and profit variability on the cropping patterns. Rice and vegetable prices, for instance, could vary considerably without affecting this pattern. Although this may be quite realistic, at least for rice, and thus indicates a range for various price policies, the scale of the resulting differences in land productivities should be used as a guide for further data checks.

Some final comments relate to model interpretation and application. To interpret projected allocation patterns in terms of the determining factors and system stability, it is important to take into account the constraint structure and the dual solution (shadow prices) at the same time. This comprehensive approach helps explain whether a certain production activity would be limited by physical, economic, or behavioral factors and how sensitive the solution would be to changes of any relevant variable. This will be demonstrated for those field crops competing for winter upland.

Figure 33 shows the marginal value productivities (MVP) of winter upland planted with four competing crops, namely winter vegetables, industrial crops, wheat, and barley. The MVP of the physical winter upland constraint is always shown as a reference, and the individual MVPs for the crops are derived as the sum of this MVP of physical winter land and of the respective flexibility.

Thus, whenever no flexibility bounds restrict a certain cropping area, the two MVPs coincide. The graphs indicate that this is true in most years for barley and, with small deviations, for wheat. Winter vegetables have a clear comparative advantage throughout the projection period, whereas the MVP of land in industrial crops is high at the beginning and declines steadily to become even less competitive than barley and wheat cropping alternatives. After 1980 industrial crops even encounter marginal losses, which means that the remaining income per hectare after deducting variable costs and opportunity costs for all nonland resources would be negative. This example demonstrates clearly that industrial crops are

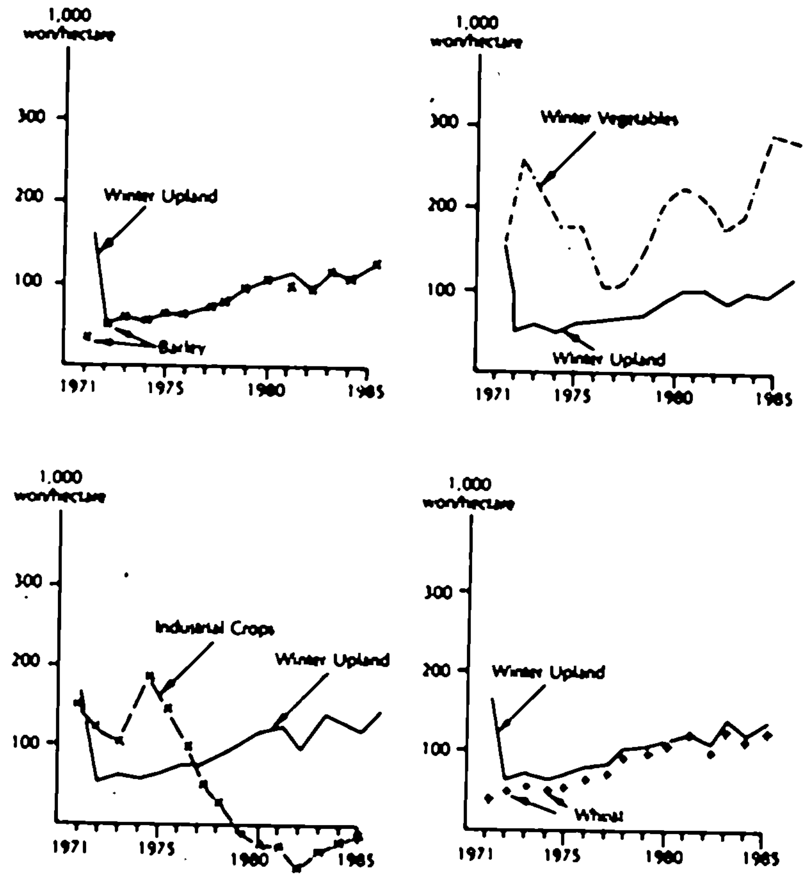


FIG. 33. Shadow prices (marginal value productivities) of physical and behavioral constraints for crops competing for winter upland.

switching from an upper to a lower bound and would, without flexibility bounds, first replace wheat and barley, then be replaced by these crops in a second phase, and disappear completely in the last period. With the exception of two years, barley would be the "residual crop" occupying the area remaining when the other crop areas are restricted by flexibility bounds.

Similar analyses to the one above could be done for all other activities, including other nonbehavioral constraints. The insight gained by this kind of analysis can be used for sensitivity and policy analysis. Such analysis may point out remaining deficiencies in data and cost items left out or incorrectly quantified. This relates to cases in which the resulting productivity gaps and trends of changing production patterns seem unrealistic. Another area for improvement revealed by such analysis might be a need for a respecification of the model and search for further, thus far unidentified, cost and return items.

Another useful result of such analysis relates to policies. Productivity differences, for instance, can be used to determine the range of price changes needed to achieve a desired reallocation. Winter vegetable areas, for example, would not be affected by price declines or cost increases, as long as the surplus return over industrial crops (in the initial years) and barley (in later years) remains positive. In the case of barley, for example, price policies leading to lower prices would in most years not affect the areas of other crops, and barley areas themselves would remain unchanged as long as the price decline would not reduce the land MVP to zero. Further price declines would cause double-cropping potential to be unused, as in the example shown in Figure 31 under the free market price alternative for barley.

This illustration may suffice to emphasize the need for comprehensive model interpretations. To conclude, for example, that winter vegetable production is not increased when prices are raised when the model assumes an upper bound is equally as misleading as to conclude that wheat production tends to be replaced by barley in the absence of a lower bound, whereas the dual solution indicates only negligible productivity differences between barley and wheat.

Although the model analyst should try to reduce the importance of the flexibility constraints by specifying explicitly more physical, technical, economic, and behavioral structures, the combination of exogenous and endogenous specification enables a flexible use in the practical planning process. Basically, the flexibility constraints stand for factors influencing resource allocation that are not explicitly known or not quantifiable with respect to their cause-and-effect relationships. The planning unit, for example MAF, can use them to impose any boundaries on the system that seem realistic. Thus, the planning process can proceed iteratively and stepwise, as it does traditionally within most governments. Three modes can be conceived. In mode 1 exogenous trend projections can be used exclusively, leaving no flexibility to the model's endogenous economic mechanisms. In this case the equation system is used to test the consistency between the projections with respect to resource use (mainly land, labor, and capital), feed supply and demand, fertilizer demand, and so on. Likewise, the resulting shadow price and cost structures can be tested for plausibility. When used with current or historical production patterns, mode 1 can be a very useful means to test the data base of the model. In mode 2 the model user can define relatively small flexibility coefficients, allowing some economically determined reallocation, which he can then interpret as shown above. In mode 3 the flexibility constraints can be widened or even dropped to allow a far-going endogenous explanation of the reallocation process. This mode of operation requires only a few or no prespecifications or assumptions concerning future production patterns on the part of the planning unit.

TENTATIVE CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

A dynamic, microeconomic model of farmers' decisions with respect to resource allocation and production was developed as a component of KASM. The major objective of this component was to simulate the year-to-year allocation of farm resources under the condition of prespecified input output relationships and initial conditions with respect to resource levels.

The component can be used flexibly, i.e., as a separate model or in an interactive mode, with input and output linkages with other KASM components. The results presented in this chapter illustrate mainly the market feedback recursively linking endogenous market prices and the respective supply response.

The presentation of results indicates both some positive features and some weaknesses of the model at this stage. The positive features are summarized first. Projections of resource allocation allow for automatic consistency checks for supply and use of inputs and fixed resources. Moreover, the market linkage establishes consistency between income and population-determined changes in consumer demand and the resulting resource allocation and production responses. The projections include further information about the economic forces underlying growth or decline of resources measured as shadow prices that cannot be obtained by nonsimultaneous system models. The results, although not yet fully acceptable, seem to support the basic hypothesis of rational behavior under limited information and the competition mechanism among human, animal, and mechanical power regulating the process of technical change in agriculture.

Conceptually, a model like this will never be complete and final. However, it might be considered as a useful basis for further analytical research and policy analysis, as well as a comprehensive information system integrating microlevel farm management data and macrolevel information for the sector as a whole.

Several weaknesses of the model have been pointed out, which should be subject to further research. The most important area for research is related to intensive checks on data consistency and general improvements in the data base, particularly in regard to production costs, mechanization, and labor requirements. Close cooperation with farm management experts will be useful. A second area relates to the aggregation level, where a breakdown into regions appears to be useful. Other needs for more modeling work include improving the structure that relates to subsistence and risk-aversion behavior, financing, and mechanization.

Besides these basic and obvious priorities, directions of research will depend on the specific problems and subject-matter areas to which the model is to be applied. Thus, a close interaction of systems scientists, economists, farm management experts, and policy makers will be permanently needed if the model is to become what it is intended to be: a conceptual and theoretical basis, with sufficient flexibility for policy analysis and application to changing problems in the field of agricultural production.

APPENDIX TO CHAPTER 9

Internal Feedback, Exogenous Feedback, and Exogenous Variables: The Formal Structure of Dynamic Linkages

1. OBJECTIVE FUNCTION COEFFICIENTS (z)

Production Activities

$$z_{jt} = z_{jt}(\hat{p}_{jt}, yld_{j,t-1}, cost_{j,t-1}) \qquad j \varepsilon AP$$

$$\text{with } \hat{p}_{jt} = \hat{p}_{j,t-1} + \frac{1}{\lambda}(p_{j,t-1} - \hat{p}_{j,t-1}) \qquad \lambda \geqslant 1; j \varepsilon AP$$

where AP is the set of all production activities, p is the producer price (endogenous to the DEMAND/PRICE component), yld is the yield per unit, and $cost$ the variable cost, including replacement. The parameter λ indicates the time constant (in years) of the distributed delay.

Investment Activities

$$z_{jt} = z_{jt}(r_{i,t-1}, v_{jt}) \qquad j \varepsilon AI; \ i \varepsilon CI$$

where to each j corresponds one specific constraint within the set CI of resources. AI is the set of investment activities, and r is an optimal shadow price; v is an exogenous variable indicating depreciation rates.

Other Activities (financing, transfers, etc.)

$$z_{jt} = z_{jt}(v_{jt}) \qquad j \varepsilon AL$$

where AL is the set of all other activities and v is an exogenous variable.

2. CONSTRAINT VECTOR COEFFICIENTS (y)

Land Areas

Generally, for physical land constraints,

$$y_{it} = v_{it} - \alpha_i \left(\sum_{j \varepsilon AR} x_{jt} \right) \qquad i \varepsilon CA$$

where y is an element of the constraint vector; CA is the set of area constraints; v stands for land resources of each type, resulting from land development or withdrawal for industrial urban land use as determined in CHANGE or by exogenous projection; AR is the set of perennial activities; α_i is the proportion of perennials using land category i (e.g., $\alpha_2 = 1$ for upland, $\alpha_1 = 0$ for paddy).

Labor

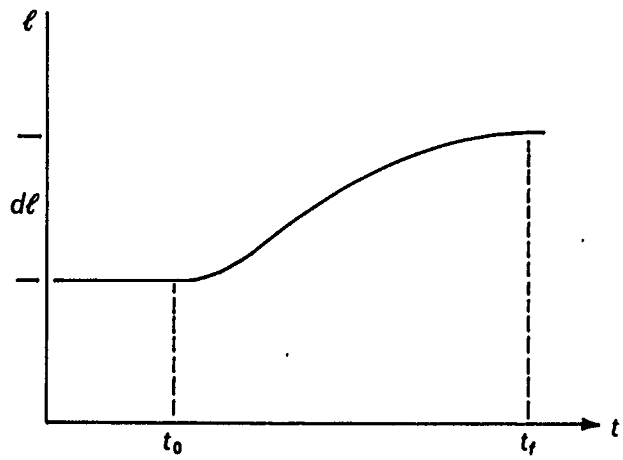
$$y_{it} = \ell_{it} \cdot AGMP_t - \sum_{j \varepsilon AQ} \sum_{s=1}^{N_j} a_{ijt} x_{j,t-s} \qquad i \varepsilon CL$$

where CL is the set of seasonal labor constraints; $AGMP$ is the peak season agricultural labor force (from POPMIG); N_j is the time (years) of gestation of perennials; AQ is the set of perennial planting activities; a_{ij} is the labor requirement of activity j in season i; and ℓ_{it} is working time equivalent in hours per season and man-equivalent unit.

The working time equivalent ℓ gradually increases over time to reflect learning and efficiency improvement. Let ℓ_0 be the current time equivalent, $d\ell$ the maximum increase of ℓ, t_0 and t_f the initial and final period of efficiency changes; then ℓ can be approximated from the following function:

$$\ell_{it} = \begin{cases} \ell_{i0} & \text{for } t < t_0 \\ \ell_{i0} + 0.5d\ell_i\left\{1 + \sin\left[\left(\frac{t - t_f}{t_0 - t_f} + 1.5\right)\pi\right]\right\} & \text{for } t_0 \leqq t < t_f \\ \ell_{i0} + d\ell_i & \text{for } t \geqq t_f \end{cases}$$

Graphically, this is shown below:



APPROXIMATION OF EFFICIENCY INCREASES OF THE AGRICULTURAL LABOR FORCE

Machinery

The machinery capacity per unit of machinery aggregate i in peak season m is expressed in seasonal labor per unit α_{im} times the effective number of units. The effective number of units depends on the previous net investment

x_{ij} and the depreciation schedule λ_i. Replacement of machinery, exceeding a maximum lifetime S_j (e.g., seven years for tillers) is exogenous:

$$y_{im,t} = \alpha_{im}\left(\sum_{s=1}^{S_j} \lambda_i^s x_{ij,t-s} + \lambda_i^1 x_{ij,t-S_j} \right) \qquad i \varepsilon CM;\ j \varepsilon IM;\ m = 1,2$$

where CM is the set of machinery packages and IM the corresponding set of investment activities.

Other Farm Capital

$$y_{it} = y_{it_0} + \sum_{s=t_0}^{t} x_{ij,t-s} \qquad i \varepsilon CC;\ j \varepsilon IC$$

where CC is the capital stock and IC is the corresponding investment, both measured in monetary terms at constant prices.

Technically Maximum Livestock Herd Sizes

$$y_{it} = x_{j,t-1} + \beta_i x_{j,t-s_j} + v_{jt} \qquad i \varepsilon CV;\ j \varepsilon AV$$

where to each i corresponds one specific j; CV is the set of livestock herd constraints; AV is the set of livestock production activities; β is the net rate of potential herd expansion per female livestock unit; v_j are imports; s is the maturation time (years) of young female animals.

Liquid Assets

$$y_{\ell,t} = \sum_{j \varepsilon AP} cost_{j,t-1}\ x_{j,t-1} - x_{sp,t-1} - x_{ba,t-1} + \sigma DIPI_{t-1} + s_{ba,t-1}$$

where $y_{\ell,t}$ is the constraint for liquid assets; AP is the set of all production activities, including internal transfer and input purchases; x_{sb} *and* x_{sp} are levels of short-term loans from banks and private sources, respectively; σ is the marginal propensity to save; s_{ba} is the level of bank deposits; and $DIPI$ is the disposable farm-household income.

The disposable income $DIPI$ is defined as agricultural value added, VA; plus nonagricultural farm income, $INNA$; minus taxes, TAX, interest and principle on long-term loans, $PINT$ and NDS, respectively:

$$DIPI_t = VA_t + INNA_t - TAX_t - PINT_t - NDS_t$$

where VA is a function of the levels of production activities, actual yields, and variable costs, including interest on short-term loans and wages for hired labor. NDS and $PINT$ depend on the long-term indebtedness of the farm sector, determined by previous levels of the respective loan activity.

Minimum Income

$$y_{M,t} = \mu(1-\sigma)DIPI + NDS_{t-1} + PINT_{t-1} + TAX_{t-1}$$

where $y_{M,t}$ is the minimum income necessary to cover unavoidable expenses; μ is the ratio between subsistence and actual consumption; σ is the average savings rate.

Flexibility Constraints

$$y_{i,t} = (1+b_u)x_{j,t-1} \qquad i\varepsilon\, UB;\ j\varepsilon\, AP$$
$$y_{i,t} = (1-b_\ell)x_{j,t-1} \qquad i\varepsilon\, LB;\ j\varepsilon\, AP$$

where UB is a set of upper bounds; LB is a set of lower bounds; AP is the set of all production activities. To each i there corresponds one particular activity j or group of activities belonging to the same crop category. Maximum change rates are b_u and b_ℓ.

Technology Adoption

$$\alpha_{i1}x_{ij,t} \leq y_{a,t} = c_i y_{i1,t} \qquad i\varepsilon\, CM;\ j\varepsilon\, IM$$

where y_a is an adoption constraint, c_i is the maximum adoption rate, α is the unit capacity in seasonal hours (per season 1), IM is the set of investment activities, and CM is the corresponding set of machinery capacity (in hours).

10 THE DEMAND-PRICE-TRADE COMPONENT OF THE KOREAN AGRICULTURAL SECTOR MODEL

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Michael H. Abkin

This chapter describes the demand-price-trade (DEMAND) component of the Korean Agricultural Sector Model (KASM), its information requirements, the variables it calculates, time-series tracking tests, and further areas in which the component can be revised and extended.

COMPONENT DESCRIPTION

The flow of information between DEMAND and the other components of KASM is shown in Figure 34. Domestic supply, population, and lagged income are major inputs into DEMAND. Food consumption, nutrition, prices, and agricultural trade flows are the principal outputs from DEMAND.

The major elements and computing sequence in DEMAND are shown in Figure 35. DEMAND projects farm demand, nonfarm demand, and trade, consumption, and nutritional accounting. In addition to a number of government policy instruments, production, population, and income are the major external forces, as represented in the diagram, that act on the component.

The heart of DEMAND is a system of consumer demand equations for food commodities for farm households and for food and nonfood commodities by nonfarm consumers. World import and export price projections link these domestic relationships to the world market and also act as bounds on internal price variations. The actual import or export levels are assumed not to affect world price levels for the commodity groups.

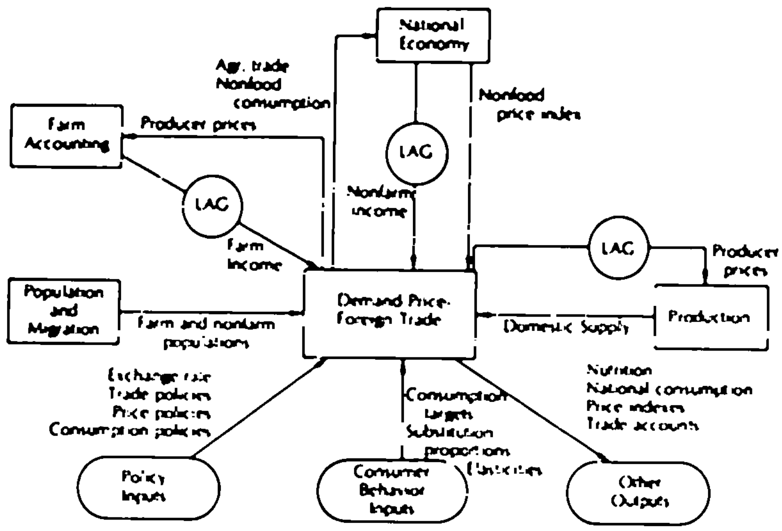

FIG. 34. Major linkages between the demand-price-foreign trade component and the rest of the Korean agricultural sector model.

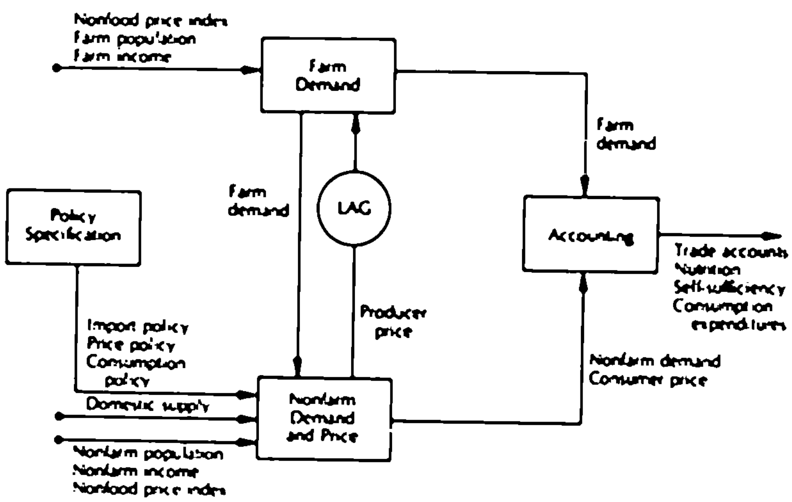

FIG. 35. Schematic diagram of the demand-price-foreign trade component.

The farm food-demand component assumes subsistence behavior by Korean farm families. In other words, farm demand does not compete with urban demand and depends on lagged farm prices and income rather than on current consumer prices and income. Indeed, farm consumption is subtracted from domestic supplies before the urban market is considered.

The nonfarm food-demand component calculates equilibrium prices and consumption levels consistent with government policies, given the projected levels of domestic supplies, income, population, and farm consumption. For any commodity, the government policy may affect either price or quantity variables, but not both. When the policy set has been determined, a matrix inversion approach simultaneously solves all demand equations together with an expenditure constraint.

Price and consumption policies in Korea, as elsewhere, have many, sometimes conflicting, objectives. Increased domestic production and high producer income may be the objectives of higher producer prices. Reduced food imports and foreign exchange costs may be the objectives of import controls, higher consumer prices, and administrative measures. Reduced inflation, controlling industrial wage costs, and maintaining the competitive position of export industries may be the goals of consumer price controls.

In order to determine the results of these and other instruments of policy, a number of policy options have been built into DEMAND. For each commodity, four mutually exclusive policies and two independent policies are defined. The mutually exclusive policies are:

1. Per capita consumption may be set and price and import/export effects calculated.
2. Import/export levels may be set and consumption and price effects calculated.
3. Consumer price level may be set and effects on imports and nonfarm consumption levels calculated.
4. Consumer price level may be bounded by either world prices or prior domestic prices *and* import/export levels set and price levels calculated, deferring to the price bounds if the two objectives conflict.

The independent policies are:

1. Government reserve stock management policies may be changed and the resulting effects on consumption, price, and import/export levels calculated.
2. Producer price may be set by policy or linked to market price and the effects on farm consumption and the nonfarm market calculated.

Each commodity must have one and only one policy from the mutually exclusive set and may have either policy (or both) from the independent set. These policy options are commodity specific, so that the policy for rice, for example, may differ from that for barley. A "default" policy set controls the model in the absence of a specific alternative policy.

Table 6 illustrates the 16 policy choices now available for each commodity. For each of the mutually exclusive policies, the decision maker can choose either kind of producer price policy and either kind of carry-over policy. One and only one of the mutually exclusive policies must be chosen for each commodity. Mutually exclusive policy 4 combines elements of 2 and 3. After the price bounds and import/export targets have been set by policy assumption, policy 4 operates like policy 2 unless the bounds are violated. In this case, the price is set at the nearest bound and policy 4 operates like policy 3. Policy 4′ would combine similar elements of 1 and 3 but is not programmed into the system at present.

The theoretical construct for DEMAND is described below. Except for the values of the numerical coefficients,[1] the farm and nonfarm demand equations are identical. Thus, only one description of the theoretical process is needed.

TABLE 6
Policy Options in DEMAND*

Mutually Exclusive Policies	Independent Policies			
	Producer Prices Set by Market		Producer Prices Set by Policy	
	Standard Carry-over Policies	Alternative Carry-over Policies	Standard Carry-over Policies	Alternative Carry-over Policies
1. Per capita consumption set by policy	X	X	X	X
2. Import/export levels set by policy	X	X	X	X
3. Consumer price levels set by policy	X	X	X	X
4. Consumer prices bounded and import/export levels set by policy, unless bounds are violated	X	X	X	X
4′ Consumer prices bounded and per capita consumption set by policy, unless bounds are violated	Not Programmed			

*Each X is a policy option.

Per capita consumption of each food commodity is related to the price of that commodity, prices of substitute food commodities, per capita income, and nonfood prices. The elasticity of own-price response[2] is constant for each commodity. The income elasticity depends on consumption levels such that the closer actual consumption is to a targeted consumption level, the smaller is the income response. This behavioral assumption ensures that consumption does not increase without bound as income increases and that consumption patterns in the long run remain consistent with reasonable expectations of long-run calorie and protein intake [164]. The substitution elasticities[3] across food demand equations are constrained so that the partial derivative of consumption of one commodity with respect to that of another commodity is constant. In mathematical terms,

$$\frac{\partial q_i}{\partial P_j} = b_{ij} \frac{\partial q_j}{\partial P_j} \quad \text{or} \quad \frac{\partial q_i}{\partial q_j} = b_{ij} \tag{1}$$

In their linearized, difference equation form for simulation in DEMAND, the consumption functions are,

$$\begin{bmatrix} q_1 \\ q_2 \\ q_3 \\ \cdot \\ \cdot \\ \cdot \\ q_n \end{bmatrix} = \begin{bmatrix} 1 & b_{12} & b_{13} & \dots & b_{1n} \\ b_{21} & 1 & b_{23} & & b_{2n} \\ b_{31} & b_{32} & 1 & & b_{3n} \\ \cdot & & & & \cdot \\ \cdot & & & & \cdot \\ \cdot & & & & \cdot \\ b_{n1} & b_{n2} & b_{n3} & \dots & 1 \end{bmatrix} \begin{bmatrix} m_1 & 0 & 0 & \dots & 0 \\ 0 & m_2 & 0 & & 0 \\ 0 & 0 & m_3 & & 0 \\ \cdot & & & & \cdot \\ \cdot & & & & \cdot \\ \cdot & & & & \cdot \\ 0 & 0 & 0 & \dots & m_n \end{bmatrix} \begin{bmatrix} P_1 \\ P_2 \\ P_3 \\ \cdot \\ \cdot \\ \cdot \\ P_n \end{bmatrix} + \text{income and intercept terms} \tag{2}$$

where

$$m_i = \varepsilon_{ii} q_i(t-1)/P_i(t-1) \tag{3}$$

is the own-price partial derivative and

$$\sum_{i \neq j} b_{ij} = -\alpha_j \tag{4}$$

is the proportion of the change in the j^{th} food consumption which is compensated by all other foods following a change in the j^{th} price.

The effect of nonfood price on food demand is obtained somewhat indirectly. Income and food prices are deflated by the nonfood price index in order to maintain the homogeneity condition. In the farm demand component, the deflation is explicit. For nonfarm demand, however, the deflation is implicit in that the nonfood cross-demand elasticity is computed as the negative sum of all price and income elasticities for each food commodity.[4]

For the farm food-demand component, this completes the description of the structure, since nonfood expenditure is obtained as a residual. The nonfarm demand component, however, includes an equation to estimate nonfood demand explicitly. In order to assure consistency with total expenditure projections, a balance equation is added to the equation set and an elasticity expansion parameter calculated to force the balance. Mathematically, the set of equations to be solved is

$$q_i = q_{i0}[f_i(\text{price, income})]^S \quad i = 1, 2, \ldots, \text{number of commodities} \quad (5)$$

$$\text{Total expenditure} = \sum_i P_i q_i \quad (6)$$

The elasticity expansion parameter (S) is constant across all demand equations at any point in time and varies over time. It proportionally changes the value of each elasticity so that the projected total nonfarm consumption expenditure equals the expenditure implied by the commodity-specific demand and price projections. The nominal value of this parameter is one, and its simulated value should remain close to one over time.

After all prices and consumption levels have been calculated consistent with the budget constraint and with the policy-specified price bounds, the emphasis shifts to foreign trade and demand accounting. DEMAND calculates net exports (imports) for each commodity as the surplus (deficit) of domestic production over feed and industrial demand, losses, stock change, and farm and nonfarm food demand. The exogenously projected world prices convert these individual surpluses and deficits into the net agricultural contribution to the balance of payments. In addition, self-sufficiency percentages are computed for each commodity. Finally, this component of DEMAND calculates the daily per capita nutritional intake of protein and calories, by nonfarm and farm populations and by plant and animal sources.

In summary, DEMAND projects total and per capita consumption levels for farm and nonfarm populations, producer and consumer prices, and nutrition and trade variables.

INFORMATION REQUIREMENTS

Several kinds of information are required to operate DEMAND. Behavior and policy parameters determine the relative shapes of the price and consumption responses, whereas the absolute response levels are determined by the values of the endogenous variables at the beginning of a run (the initial conditions). Exogenous variables, which are determined outside of DEMAND and which can change from one time period to the next, are the driving forces to which the component responds.

Parameters

The parameters of the model can be classified as (1) policy parameters, (2) behavioral parameters, and (3) accounting coefficients, depending on whether or not they characterize public or private actions or express identity relationships, respectively. In DEMAND the *behavioral parameters* characterize the income and price responses of the demand equations. These include the long-run limiting consumption levels, own-price elasticities, substitution proportions, and the relative slopes.

The income response of demand is partially determined by the consumption limits. These are the levels of per capita consumption beyond which additional income will not affect per capita consumption. That is, the income elasticity goes to zero as consumption approaches the limits.[5]

The price response of demand depends on the own-price elasticity, the substitution proportions, and the relative slopes. The own-price elasticity is the percentage change of consumption of a commodity resulting from a change of 1 per cent in its own price, all other prices and income held constant. The substitution proportion for a given commodity characterizes the quantity change in the consumption of all food commodities as a result of a change in the price of a given commodity. (This is the column sum of the elements of the first matrix in equation (2).) The relative slopes are the per cent of the change in the consumption of one food item resulting from its own price change, which is in turn caused by an opposite change in the consumption of another food item. (These are the off-diagonal elements of the first matrix in equation (2).)

Government *policy parameters* in DEMAND include the exchange rate, stock levels, farm price policy, bounds on consumer prices, and nonfarm price or quantity policies. The exchange rate used in DEMAND is the official rate of the Korean won per U.S. dollar. The stock level is the amount of each commodity required to satisfy the desired number of months of consumption held in government, household, and private market inventories at the beginning of the crop year; it may vary among commodities.

The farm price policy parameter specifies whether producer prices are set by government policy or whether they are linked to consumer food prices by marketing margins. If producer prices are set by policy, the projected time path of these prices must also be specified.

The consumer food price bounds are upper and lower limits outside which the domestic food price is not permitted to rise or fall. These bounds are expressed as proportions of the world price or of the consumer price in the previous period, or both.

Corresponding to each policy in the mutually exclusive policy set (Table 6) — where the analyst must set either price, per capita consumption, or import levels — is a data set containing the projected time path of that particular variable. In addition, a separate parameter indicates which policy is chosen.

The major *accounting coefficients* in DEMAND express the nutritional content of the food commodities (protein and calorie), convert grains to a polished grain equivalent, and express the margin between farm and consumer prices. The marketing margins show the per cent markup between farm and consumer prices. This markup may vary among commodities but is a constant proportion through time.

Initial Conditions

The initial condition data for a model are the starting values of the endogenous state variables. In other words, they are the last real-world observations before the model beings to work. For DEMAND as a component of KASM, this base-year data is for 1970 in the verification runs and 1974 for projections.

The initial stock levels are the November inventories held by households, government, and at ports in the year prior to the base year, e.g., 1969 or 1973. They exclude stocks held in private and cooperative marketing channels.

The initial levels of per capita consumption are calculated in the model to agree with the food balance data for 1970 or 1974 as reported in KASS Special Report 11 [164]. The national per capita consumption levels are made consistent with the supply available for human consumption and the farm/nonfarm ratios of per capita consumption.

The initial consumer price levels are the base-year retail prices in Seoul. The initial producer prices are the prices received by farmers or unit value of production in the base year. Producer prices in 1969 are used to initialize the lagged prices used in the farm consumption functions.

The income elasticity of demand is not directly observable but must be inferred from other data. The values used in the base year for the model were cross-section estimates adjusted to track the 1970–74 time period.

Exogenous Variables

The exogenous factors of DEMAND are population, income, food supplies, nonfood prices, and world prices for food imports and exports. Both farm and nonfarm population levels and per capita farm and nonfarm disposable income are demand shifters. They set the overall level of demand.

The domestic supply of food for human consumption is the balance remaining after losses, seed, feed, and industrial demands are subtracted from the harvest and carry-over. Feed, seed, losses and industrial demands are calculated in the production component of KASM.

The nonfood price index deflates the observed food price changes to remove overall inflationary trends and obtain real price changes. Its value is one in the base year. The world prices for imports and exports are calculated by interpolating projections of international commodity prices derived from the World Bank (IBRD) [67]. Import prices are assumed to be 20 per cent higher than the export prices for similar commodities, reflecting a margin for transportation and handling. The assumed margin in the case of rice and barley is 30 per cent. In addition to these purely exogenous variables, lagged endogenous variables also affect the demand relations.

Endogenous Variables

Endogenous variables are calculated inside DEMAND. They may be determined either jointly or in sequence within the component. The endogenous variables of the component may be either observable or nonobservable in the real world. Observable variables correspond to data series obtained by direct observation of the real world, e.g., market prices. Nonobservable variables are time-varying parameters of the model and can only be inferred from observed data, e.g., the income elasticity of demand.

The observable variables in DEMAND are consumption, price, nutrition, import/export levels, and the agricultural contribution to the balance of payments. Consumption levels of food are calculated for the farm and nonfarm populations, both on a per capita and total basis. Total and per capita expenditures on food and nonfood items, as well as the physical amounts of food, are also calculated in the model.

The consumer price of food commodities corresponds to the retail price in Seoul, as reported by the Economic Planning Board. The corresponding producer price is either the unit value of production or the national average price received by farmers. The price received by farmers is used for beef, pork, chicken, and eggs.

Nutrition is calculated as the per capita daily consumption of protein and calories separated into those from plant and animal sources and by farm and nonfarm consumers.

The import and export levels are the number of metric tons required or remaining after food, feed, and industrial demands; losses; and stock changes have been subtracted from domestic production and carry-overs. The agricultural contribution to the balance of payments is the accumulated value of these deficits and surpluses.

The nonobservable variables in DEMAND are time-varying parameters in the relationships, which include the income elasticity, the cross-price elasticities of demand and the corresponding partial derivatives, and the elasticity expansion parameter.

COMPONENT TESTING

DEMAND has been tested continuously in the course of its development. Indeed, successive changes and improvements resulted from those tests. Early tests examined the price response of changing supplies for various commodities, and results of these tests led to a generalization of the policy options built into DEMAND, particularly the inclusion of price bounds.

Later, significant effort was invested in compiling price and consumption time series and in estimating demand relationships for farm and nonfarm consumers [166]. These data were used to improve the consistency of the initial conditions of the model.

In addition, intensive "manual" tuning of the elasticities and substitution relationships helped the model to track the actual 1971–74 national average per capita consumption levels, using actual prices and income in that period. For most commodities, "good fits" were obtained, where the goodness of fit for each commodity was measured by the normalized sum of squared errors. Specifically,

$$F_i = \sum_{t=1971}^{1974} \left(\frac{C_{it} - \hat{C}_{it}}{\bar{C}_i} \right)^2 \qquad (7)$$

where C_{it} is actual per capita consumption of commodity i at time t, $\hat{C}_{it}$ is simulated consumption, and $\bar{C}_i$ is the mean value of the time series; i.e.,

$$\bar{C}_i = ¼ \sum_{t=1971}^{1974} C_{it} \qquad (8)$$

The following list shows the results of these tests, where a perfect fit would give a zero value of F.

Commodity	F*	Commodity	F*
Rice	.013	Tobacco	.309
Barley	.012	Industrial crops	.410
Wheat	.070	Beef	.083
Other grains	.115	Milk	.633
Fruit	.014	Pork	.005
Pulses	.020	Chicken	.011
Vegetables	.025	Eggs	.046
Potatoes	.028	Fish	.058

*Normalized sum of squared errors.

FURTHER IMPROVEMENT AND EXTENSION

In its current form, DEMAND has been shown to be a practical and useful model for projecting future levels of prices, consumption, trade, and nutrition in Korea. This does *not* mean, however, that improvement and extension of its capabilities are not possible or desirable as time and resources permit. This section outlines a number of changes that would improve and increase its capabilities The farm demand component, government nonprice policy analysis, and the empirical base for the model are suggested for possible extension and improvement.

The farm demand component can be revised on a number of fronts. Three will be mentioned. The method of calculating the nonfood expenditure by farm people can be revised to parallel the method used in the nonfarm sector. The current method calculates nonfood expenditure by subtracting food expenditures from farm income. The revision would involve estimating a nonfood demand equation for farm people and adapting the solution algorithm of the nonfarm component to the farm component.

The nonfood expenditure calculation is part of a more general problem of farm-household behavior. The allocation of consumption and investment expenditures in farm households is somewhat more complicated than in nonfarm households and certainly has a significant impact on output in the agricultural sector. Dong Min Kim [88] has developed a preliminary model of the farm household that can guide revisions in this direction.

A third revision for the farm component of DEMAND would be to shift from the subsistence farm assumption to a market-oriented farm assumption. This would relate the market demand in the farm sector to current consumer prices in addition to (or in place of) lagged producer prices. The farm and nonfarm demands would be added together and, with supply, would jointly determine the market price, rather than the present sequential, noninteractive market mechanism.

The Korean government has pursued a number of policies aimed at affecting food consumption without altering the price structure. These nonprice policies have included riceless days, mixed grains, flour foods (honshik, boonshik), and various other promotional devices. Although the effects of these policies have been analyzed as necessary on an ad hoc basis, it is desirable to formalize the analytical capability to address these issues. In this regard, it is important that the kinds of nonprice policies that may be employed by the government be foreseen and modeled, perhaps as proportional shifters of the price-income demand curves.

Another area for further investigation is the empirical base for the model. Indeed, such an investigation could probably expand econometric theory and methodology in addition to improving KASM. This work could proceed along a number of lines.

DEMAND has evolved from a constant price elasticity system to a linear substitution system. The next logical step in this evolution would be a totally linear system of demand equations. Methods to estimate the entire system of linear demand equations including an expenditure constraint exist in the literature.[6] Stone's method [158, 159] estimates expenditure as a linear function of commodity prices and income. The expenditure constraint reduces the free parameters in each demand equation to two and results in a singular covariance matrix for the system of equations. However, estimation methods have been developed in spite of this singularity [143].

The primary benefit of such an approach is that the statistically estimated model and the computer simulation model would be of the same structure. Hence, the simulation model would be consistent with the estimation procedure used to derive parameter values from observed data. As a result, there may be less need to adjust the coefficients or results.[7]

A number of nuances in the existing computer model challenge econometric methods of estimation. If the constant price elasticity demand model were retained, it should be reestimated in the same form as the simulation model. A constant elasticity of demand model consistent with an expenditure constraint has been examined by Theil and Barten [19, 20, 162, 163]. The result is a model that is not linear in either the parameters or the price, quantity, or income variables. This could replace the elasticity expansion approach to the budget constraint currently used, since the estimated elasticities in such a model would already constrain total expenditure.

The present income elasticity specification in the computer model is a two-part econometric challenge. The first part of the challenge is to solve the nonlinear partial differential equation[8] it implies. The second part is to statistically estimate the parameters of the closed-form solution. This, like the Theil-Barten demand equations, will be nonlinear in both the parameters and the variables.

11

DATA REQUIREMENTS AND PARAMETER ESTIMATION

Alan R. Thodey

It is well known that the estimates and projections made by a simulation model can only be as good as the data and structural assumptions upon which they are based. The Korean Agricultural Sector Model (KASM) is no exception. Are the data required by KASM readily available? If so, are these data accurate, consistent, and timely? This chapter examines these questions, together with some of the items considered in defining commodity groups and in using the available data. The question of whether the model includes all relevant data is not considered.

A relatively detailed agricultural sector model, such as KASM, requires an enormous amount of information. Since the model requires that all relationships be explicitly expressed in quantitative terms, almost all of this information must be incorporated in the model as numbers. This requirement is demanding for any agricultural sector, but particularly so in situations where the agricultural data base is incomplete and of limited duration. In fact, in most such situations, developing and operating such a model is difficult, if not impossible. In the case of Korea, however, the existing data base permitted such a model. This data base was improved markedly in the early 1960s in response to the initiation of economic planning. In particular, by the beginning of the Second Five-Year Economic Development Plan, 1967–71, the coverage, methodology, and collection of agricultural and economic statistics, among others, had been significantly improved. This does not mean, however, that further improvement is neither possible nor desirable.

TYPES OF DATA REQUIREMENTS

The data required by each component of the model generally fall into four categories:

1. Lagged endogenous variables. For the first period of the model, these are the initial conditions (or base values) of the variables to be projected by the model and are based on observations in the real world, where possible. In subsequent periods model output from previous periods is used (together with the initial conditions, if required). These variables may come from the same or other components of KASM.
2. Exogenous variables. The initial and projected values of these variables are derived outside the model by various methods and are given to the model as input.
3. Technical, institutional, and behavioral parameters. These are incorporated in relationships containing the predetermined variables (1 and 2 above) and are used to project the endogenous variables subject to the policy parameters. The initial and projected values of these parameters are generally predetermined, although some may be endogenously determined.
4. Policy parameters. The set of policy options is given from outside the model (precise specification resulting from interaction between decision makers and analysts) and provides the framework for projecting the endogenous variables and parameters.

Examples of the four types of data required in each component of KASM are shown in Table 7. For example, the population component uses the population by age, sex, and sector in the previous period as its base for projecting births, deaths, and migration in each period (year). Projected exogenous variables, such as the level of urban unemployment, are used in determining year-to-year variations in these projections. Also, by varying the nature of the government's population control (family planning) program, it is possible to raise or lower birth rates. In the present version of the component, this must be done by readjusting the behavioral parameters (birth rates), although it could be incorporated directly once the relationship between government programs and birth rates is established.

COMMODITY GROUPINGS

In the components of the model related to agricultural production, consumption, and trade, we distinguish 19 agricultural and one nonagricultural commodity groups. They are:

1. Rice
2. Barley
3. Wheat
4. Miscellaneous grain
5. Fruit
6. Pulses
7. Vegetables[1]
8. Potatoes[1]
9. Tobacco
10. Forage
11. Silk
12. Industrial crops
13. Beef
14. Milk
15. Pork
16. Chicken
17. Eggs
18. Fish/seaweed
19. Residual food
20. Nonagricultural

The nonagricultural group is further divided into subgroups in the national economy component.

The agricultural commodity groups selected represent a compromise between narrow groupings of relatively homogenous commodities and a manageable number of groups, both in terms of the model and data generation. The major commodities are specified separately, such as rice, barley, and wheat. In addition, the livestock products are specified separately because of their own unique production characteristics. Other commodities are grouped together. For some purposes, additional groupings have been necessary, such as the production of summer, fall, and winter vegetables. Certainly further subdividing fruits, vegetables, potatoes, and industrial crops would be desirable for many purposes. To do so throughout the model, however, would substantially increase its size and operating cost.

In almost all cases, commodities are measured at the farm level in the same form as specified by the Ministry of Agriculture and Fisheries (MAF). These forms are shown in Table 8. Also shown are some of the more important items contained in each commodity group. It should be noted that within groups, commodities are simply aggregated without reference to relative value, nutritive content, or other factors. Hence, apples are considered as equal to oranges as they are to peaches.[2]

AVAILABILITY AND QUALITY OF DATA

For projection purposes, the base year used in the model should be the most recent year for which a complete set of data is available, which means that the base-year data in the model should be updated annually. For validation and verification purposes, however, it is desirable to use an earlier base period, so that projections can be compared with reality. KASM currently stores time-series data beginning with 1970 through the current year for which data are available. These series can be used to initialize the model in any year within the period for which data are stored. For example, the model can be initialized in 1970 for verification purposes

TABLE 7
Examples of Types of Data Requirements in KASS Model Components

Component	Predetermined Variables			Technical, Institutional, and Behavioral Parameters	Policy Variables and Parameters
	Lagged Endogenous				
	Within Component	Outside Component*	Exogenous		
Population (POPMIG)	Population by age, sex, and sector	Nonagricultural employment	Urban unemployment	Birth rates Death rates Migration rates	Population (birth rate) control Nonagricultural employment of farm population Military manpower
Crop technology change (CHANGE)	Crop yield Input use Land classes	Prices Crop areas Farm income Tree crop age composition	Land development costs Maximum potential land area improvement Private nonfarm capital	Diffusion rates Input demand elasticities Farm consumption-investment ratio	Land and water development investment Crop improvement Extension services Agricultural finance policies
Farm resource allocation and production (RAP)	Cropping patterns Herd sizes Capital stock Farm savings	Producer prices Input prices Farm labor available Land available Crop yields	Livestock yields	Resource requirement coefficients Maximum credit ratio Depreciation rates Maximum change coefficients	Agricultural finance policies Feed grain imports (maximum)
Demand price trade (DEMAND)	Per capita consumption Producer prices	Population Agricultural supply Agricultural income Nonagricultural income	Target per capita consumption World prices	Income elasticities Own-price elasticities Substitution proportions	Price policies Food consumption policies Exchange rates Foreign trade policies
National economy (NECON)	Capital stock Gross investment Per capita consumption	Nonfood expenditures Agricultural input demand	Labor productivity Nonagricultural exports World prices	Input-output coefficients Price and income elasticities for nonfood items Profit and capacity utilization elasticities for investment	Public consumption Public investment Price policies Import substitution Tax rates

*Assumes all components are linked. If not linked, then these are exogenous variables.

TABLE 8
KASS Commodity Groupings: Form and Composition

KASS Commodity Group	Form	Commodities Included
1. Rice	Polished grain equivalent	Nonglutinous Glutinous
2. Barley	Polished grain equivalent	Common Naked
3. Wheat	Grain	Wheat
4. Misc. grain	Grain	Corn Millet Rye Sorghum
5. Fruit	Edible harvested fruit	Apples Grapes Oranges Peaches Pears Persimmons
6. Pulses	Grain	Green bean Red bean Soy bean
7. Vegetables a. summer b. fall c. winter a/c summer winter	Edible harvested vegetable	a. Cabbage Carrot Eggplant Ginger Muskmelon Parsley Strawberry Watermelon Welson onion b Chinese cabbage Radish c. Garlic Onion Spinach a/c Cucumber Lettuce Pumpkin Red pepper Tomato
8 Potatoes	Fresh Tuber	Sweet White
9 Tobacco	Green Leaf	Burley Virginia
10. Forage	Fresh (as harvested)	
11. Silk	Raw silk	
12 Industrial crops a. edible b inedible	As harvested	a. Perilla Rape Sesame Sunflower b Castor bean Cotton Hemp Black rush
13. Beef	Fresh meat	
14. Milk	Fluid	
15 Pork	Fresh meat	
17. Eggs	Fresh unshelled	
18. Fish and seaweed	Fresh (as caught)	Fish Whales Crustaceans Mollusks Other aquatic animals Seaweed
19. Residual food	Fresh meat	Goat Rabbit
	Fresh	Edible offal
	Processed	Animal fat Chemical spices Salt Sugar
	Dried	Cocoa Coffee Tea

and in 1975 (or later, as data become available) for policy analysis purposes. All data relate to a 12-month calendar-year period.

Data from the mid-1960s exist in Korea on almost all variables included in the model.[3] Population, agricultural, fishing, and mining and manufacturing censuses are conducted periodically; farm- and urban-household surveys are conducted continually and reported annually; producer, wholesale, and consumer prices are monitored and reported; crop area, yield and production, and livestock numbers and production are estimated annually; and so on. These data generally become available in less than one year. Nevertheless, there are some important data gaps, such as losses associated with harvesting, storing, transporting, and processing; inventories held by the private market and cooperatives; quantity of agricultural commodities consumed by industry and as feed; and conversion factors for agricultural products.

In Korea, the accuracy and consistency of relevant data are perhaps more important than their availability. Until recently, most of the agricultural statistics in Korea, although estimated by trained crop reporters, had to be approved by local officials and passed through the administrative structure to the Ministry of Agriculture and Fisheries (MAF). The final published estimates tended to be biased, often depending on economic and political factors. For example, during the period of forced sales of grain to the government, the planted area was underreported. After these sales were abandoned and following the government's decision to control fertilizer distribution rigidly on the basis of planted area (with grain crops receiving priority), the planted area tended to be overreported. Reported crop yields also appear to have been influenced by various factors, such as the expectation by higher authority that target average yields had been achieved. These types of problems are well recognized and are by no means particular to Korea. Recently, improved data collection, handling, and analysis methods have been initiated. In 1974, for example, the Bureau of Agricultural Statistics, MAF, established an independent statistics collection network, which insulated data collection from management by local and provincial level administrative officials.

In addition to problems of accuracy, much of the available data appear to fail the test of consistency.[4] For example, the estimates of per capita food consumption derived by different surveys and different methods are quite different for most years. This divergence can be seen for rice, for example, in Table 9. Remembering that most effort is probably applied to collecting data on rice, the most important food in Korea, the estimates for other crops are probably even less certain. In part, some of these differences result from differences in the definitions used and in the methodologies employed. For example, the food balance sheet approach is based on estimates of production plus imports less decreases in stocks. The KASS estimate in Table 9 defines production as "harvested production," whereas the Food Bureau defines it as "production standing in the field before harvest" (crop-cutting survey estimates). The difference is the adjustment for estimated harvest losses. Similarly, some of the definitions in the farm- and urban-household surveys are not consistent with each other.

Some of the available data could be used without modification in the model to represent the base-period value of those variables. In other cases, conversion of the existing data into another form was necessary. And finally, substantial manipulation and/or adjustment of some data were required to derive consistent base-period estimates satisfactory for use in the model. For example, obtaining estimates of per capita consumption by the farm and nonfarm populations required that the basic data be changed in order to meet accuracy and consistency standards and that estimates be made of the farm-nonfarm split in total consumption.[5]

PARAMETER ESTIMATION

The technical, behavioral, and institutional parameters used in the model were derived in various ways. At one extreme, parameters were already available or were estimated as a simple relationship between two variables where the data were readily available. Fitting into this category are marketing margins between producer and consumer prices, some of the input requirements per unit of output, and savings ratios. At the other extreme, parameters were derived by judgments, based on background estimates and the reasonableness of the resulting projections by the model; most of the elasticities fit into this category. Most parameter estimates fall between these two extremes and are generally based on available Korean data.

The model is generally sensitive (i.e., responds nonnegligibly) to changes in many of the income and price elasticities of demand used in the demand-price-trade component. As a result, the estimation of elasticities has received considerable attention and is discussed briefly to illustrate the parameter estimation process used. In the first version of the model, the elasticities were mostly judgments based upon the knowledge and intuition of several specialists. More recently, the per capita food consumption estimates for 1965–74 developed for base-line use in the model [164] were used to estimate price elasticities of demand [166]. In addition, recent cross-section expenditure data from the farm- and urban-household surveys were converted into quantity terms, grouped according to the KASS commodity categories, and used for estimating income elasticities of demand [166]. This permitted all of the time-dependent factors to be held constant. With various commodity groupings, data from these same sur-

TABLE 9
Average per Capita Rice Consumption Estimated by
Various Methods and Sources, 1965–74
(in kg per person per year)

Year	Consumer Survey Method			Balance Sheet Method		
	Grain Consumption Survey*	Farm and Urban Household Surveys: Quantity†	Farm and Urban Household Surveys: Expenditures‡	KASS§	Food Bureau ‖	FAO/Korea#
1965	120.4	119.4	. . .	124.4	. . .	130.6
1966	124.2	120.5	. . .	111.4	. . .	111.9
1967	133.2	126.7	. . .	119.9	. . .	128.7
1968	132.7	118.9	. . .	113.7	118.3	117.6
1969	127.0	115.7	. . .	116.1	120.2	113.6
1970	135.9	130.3	. . .	125.4	130.9	131.7
1971	135.2	122.6	. . .	135.4	140.2	137.8
1972	133.7	112.8	. . .	120.6	125.1	127.6
1973	128.3	127.0	127.6	116.6	121.1	122.2
1974	126.9	. . .	. . .	124.1	128.8	133.6

*Ministry of Agriculture and Fisheries. Calendar-year basis.

†Ministry of Agriculture and Fisheries and Economic Planning Board/National Agricultural Cooperative Federation. Quantity of purchases reported. Calendar-year basis.

‡Quantity of purchases derived from expenditure reported, estimated using prices received by farmers and Seoul retail prices. Calendar-year basis.

§Korean Agricultural Sectory Study Rice-year basis.

‖ (MAF). Rice-year basis.

#Food and Agriculture Organization (U.N.) Korea Association, "Food Balance Sheet." Calendar-year basis.

Source: Alan R. Thodey, "Food and Nutrition in Korea, 1965–74," Special Report 11, National Agricultural Economics Research Institute/Michigan State University, 1976, Table 4.5 and Appendix 8.

veys for 1965 to 1974 were used to estimate also both income and price elasticities of demand. Many of the resulting estimates of the price elasticities, particularly the cross-price elasticities, were inconsistent with normal expectations, including the expectation of negative own-price and positive cross-price elasticities of demand. As a result, the relationships between the quantity changes of close substitutes, such as all grains and all meat products, were also analyzed. The model was then adjusted to incorporate matrices of substitution relationships between all grains and all meat products to be used by the model to compute cross-price elasticities on the basis of the own-price elasticities and projected changes in relative consumption levels. This method was adopted because it appeared to be easier to obtain estimates of substitution relationships than cross-price elasticities directly.

The actual income and own-price elasticities and substitution proportions used in the model were based on the above analyses but were subsequently adjusted to better reflect expected behavior. These adjustments were mostly based on the judgments of specialists familiar with actual price behavior.

In statistically estimating parameters, three types of errors were often encountered that resulted in the need for the judgmental adjustment of the estimated parameters. First, many of the data contain errors of both accuracy and consistency. Second, relevant variables were omitted from the estimating relationships. This occurred for various reasons: data were not available; observations (years of data) were insufficient to permit inclusion of additional variables; and the structural relationships were not fully considered. Finally, some of the types and forms of relationships used were possibly wrong; for example, all time series data were converted to logarithmic form.

PROJECTION OF EXOGENOUS VARIABLES

As the examples of Table 7 suggest, the model incorporates a substantial number of exogenous variables. These variables must be projected outside the model and then incorporated into the model. Some of these projections were derived directly from existing sources, such as projected world food and nonfood prices from the World Bank. Most, however, were projected through "off-line" analysis based on the available data for Korea and other relevant countries.

The demand-price-trade component, for example, includes a projection of per capita consumption beyond the projection period, that is, for some time after the year 2000. These projections (targets) are used to adjust the income elasticities of demand over time to maintain consistency with these expected long-term consumption patterns. They were derived as a "best judgment" by food and nutrition specialists in Korea and provide a reasonable intake of energy and protein. First, present and foreseeable consumption trends were considered; the Japanese experience was considered invaluable in identifying these trends. The trends were then subjectively adjusted for the response expected from the government as a result of being increasingly realized; for example, meat consumption was reduced substantially below trend levels because of the projected lack of domestic feed supplies and likely policies aimed at limiting consumption increases. Also, the effect of diminishing marginal utility was considered for all foods. Finally, the projections were adjusted for their nutritive content relative to expected and required nutritional levels. This was an iterative process in which the specialists responded to proposed targets and ultimately came to a general consensus.[6] Of course, these targets can be expected to change as the underlying assumptions change and as improved data become available.

Another set of projections, based on a substantial research effort, focused on the results of land and water development programs. This effort involved using a lir- programming model to identify various optional alternatives.[7] The crop technology change component, developed later, now projects land and water development activities and their consequences endogenously in KASM.

POLICY VARIABLES AND PARAMETERS

Since the model aims to provide relevant analyses for agricultural sector decisions at the national level, it is necessary to include the major policy options available as variables in the model. The process of identifying the relevant types of policies is iterative and involves interaction with the decision makers. This interaction is even more critical in selecting the values to be attached to these policy variables and parameters when alternative policies are being analyzed.

CONCLUSIONS

The sector model requires a very large amount of data, both for the base period and the projection period. Although most of the relevant data are available in Korea, questions of accuracy and consistency remain. Further, the data in general do not permit very complex or sophisticated estimation techniques to be employed. Hence, a considerable effort was required to adjust to the variable and parameter estimates to be consistent with the best judgment of the specialists.

In summary, the process of developing and maintaining an appropriately accurate and consistent data set for use in a system simulation model and a current and relevant set of structural relationships is a large and continuous task. It requires that the variables, parameter estimates, and structural relationships be continuously updated as new data and other information become available. Ultimately, the quality of the projections depends on the quality of the fundamental bases of the model, that is, the structure, the parameter estimates, and the initial condition data, which include projections of exogenous variables. A substantial manpower commitment is required for this purpose.

In spite of such problems with existing data, sector simulation models of the KASM type are useful aids in making projections for planning and policy analysis purposes. Indeed, projections must be made using whatever data are available, with or without formal models. A structurally consistent simulation model can extract a richer and more consistent set of projections from a given data set than can more informal models. In fact, the argument can be made that projections based on models with sound structural design but poor data are likely to be of higher quality and usefulness than those based on models using excellent data but designed with unrealistic, incomplete, or inconsistent structure. Further, a system simulation model provides the facility for conducting sensitivity analyses to identify those data and parameter estimates that are relatively more important in influencing projection results; thus priorities can be established for improving the quality of data.

12
USE OF A SYSTEM OF MODELS FOR AGRICULTURAL DECISION ANALYSIS

Michael H. Abkin
Fred A. Mangum, Jr.

PROBLEMS AND SUBJECTS

In the last several chapters we have conceptualized and described the Korean Agricultural Sector Model (KASM), a subject-oriented system of models designed for use in agricultural decision analysis in Korea. Our focus has been not on the private, agriculture-related decisions made by producers, marketers, and consumers, but rather on the decisions made by public decision makers concerning national agricultural policies, programs, and projects at the sector and subsector levels. These public decisions help shape the environment within which the private decision makers act. KASM is intended to contribute to the analysis phase of the public agricultural decision-making process in Korea by providing some information on the likely consequences of alternative courses of action (decisions).

For our purposes, a problem is defined as a situation in which a specific decision has to be made. When faced with such a situation, a decision maker always uses a model specifically designed to analyze the problem at hand. The nature of this model — a problem-oriented model — can range from a mental image held by the decision maker to a formal, computerized, mathematical model. More generally, a problem-oriented model is composed of many kinds of models — mental images, verbal descriptions, paper-and-pencil calculations, and computer programs — all interacting with the decision maker in arriving at a prescription for action. This fact becomes apparent when one realizes that no single type of model can provide all the analytical information necessary — political, economic, social, logistic, financial, physical — on which to base public decisions relating to agricultural development. Therefore, decision makers typically draw upon many sources, many models, to develop the specific problem-oriented model(s) used in the analysis of specific problem(s). (See chapter 2 for a detailed discussion.)

Similarily, we call a well-defined set of decisions or problems a subject area. A model capable of being used as part of problem-oriented models for analysis of problems belonging to such a set is called a subject-matter model. In the context of a specific problem analysis, a formal subject-matter model — such as KASM or relevant parts of it — is combined with other relevant models to form the specific problem-oriented model.

In this chapter, we describe the process whereby KASM, a subject-oriented system of models, can be used in problem analysis. In addition to describing the process, illustrated with an actual instance of such an application, we discuss the need and tests for credibility and present as an example KASM's use in the process of formulating Korea's Fourth Five-Year Economic Development Plan. In addition we illustrate the use of part of the KASM system with an example of rice consumption analysis. Finally, we draw conclusions for model use and development. But first we will summarize KASM as a subject-oriented system of models, its problem set domain, and the decision entry points of its components.

KASM: A SUBJECT-ORIENTED SYSTEM OF MODELS

In this section we draw together from the preceding chapters, particularly chapter 5, a summary of the problem set (subject) domain of KASM as a whole and of each of its component parts. Included is a discussion of the decision entry points where model users — i.e., analysts and decision makers — may interact with KASM to make assumptions related to particular problem analyses.

Problem Set Domain

The domain of a subject-matter model is the set of problems it is designed to address. The problem set domain of KASM is a subset of all the problems facing Korean public decision makers at the national level who are concerned with formulating medium-term to long-term (5- to 25-year) plans, policies, programs, and projects for Korea's agricultural sector and subsectors.

Figure 36 shows the problem set domain of KASM as a proper subset of the set of problems with which Korea's national, public, agricultural decision makers deal. Excluded from the inner circle in Figure 36 but included in a larger one are, for example, problems of a seasonal and short-run

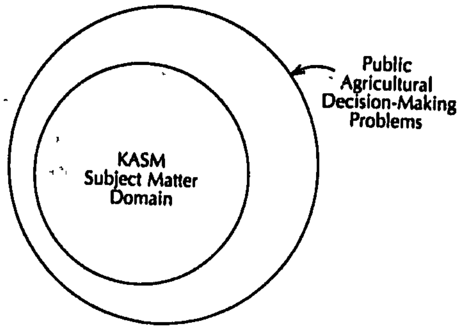

FIG. 36. The subject-matter domain of the Korean agricultural sector model relative to public agricultural decision-making problems: totally relevant.

nature (such as those related to the government grain management program addressed by the models described in part four of this book); administrative and logistical problems related to public regulation, guidance, and administration of the agricultural sector; problems of the sectors that process and market agricultural products and inputs; and problems pertaining to specific localities or regions or to differences among them.

The five components of KASM (see chapter 5, Figure 16) each carve out a portion of the subject domain corresponding to one of the five essential aspects of any agricultural sector analysis.

1. The population and migration component (POPMIG, chapter 6) projects farm and nonfarm populations and the agricultural labor force.
2. The national economy component (NECON, chapter 7) models the important feedback linkages between agriculture and the rest of the economy.
3. The demand-price-trade component (DEMAND, chapter 10) projects consumption and nutrition in farm and nonfarm households, as well as producer and consumer prices and agricultural foreign trade.
4. The resource allocation and production component (RAP, chapter 9) allocates land, labor, and capital to the production of various crop and livestock commodities and to machinery investment, consistent with labor and land constraints supplied by other KASM components and with the level of agricultural technology.
5. The all-important technological development of agriculture is projected in the technology change component (CHANGE, chapter 8), which determines crop yield levels; application rates of fertilizer,

chemical, labor, and other inputs; and the quantity and quality of various categories of land.

With a problem defined as a situation in which a decision has to be made, it is clear that the set of problems facing national, public, agricultural decision makers (represented by the larger circle in Figure 36) is dynamic and ever changing. Problems come, go, and change as Korea itself — including the values and goals of its people — and the world around it evolve over time. If the subject domain of KASM and, therefore, KASM itself remain static in the face of this dynamism, a situation such as that depicted in Figure 37 can and will arise: where part or all of KASM (lying outside the larger circle) is irrelevant or wrong and thus is useless to Korean agricultural decision makers. In fact, because of observation errors and time lags involved in, first, recognizing and identifying changes in the problem set (the larger circle) and, then, in defining and accomplishing modifications in the models (the smaller circle), a portion of KASM will always be irrelevant. Therefore, it is the responsibility of the investigative unit maintaining and using KASM to set priorities and work continuously to keep small and relatively unimportant that portion of the smaller circle which is not overlapped by the larger circle.

Even if we assume the ideal situation shown in Figure 36, there are relevant problems that lie outside the KASM subject-matter domain. In such cases other formal models, such as the Grain Management Program model discussed in chapter 14, and/or informal models are used in problem-solving analysis. Furthermore, aspects even of problems within the purview of one or more of the KASM components must be analyzed with information from other formal and/or informal models supplementing information from KASM, i.e., a problem-oriented model.

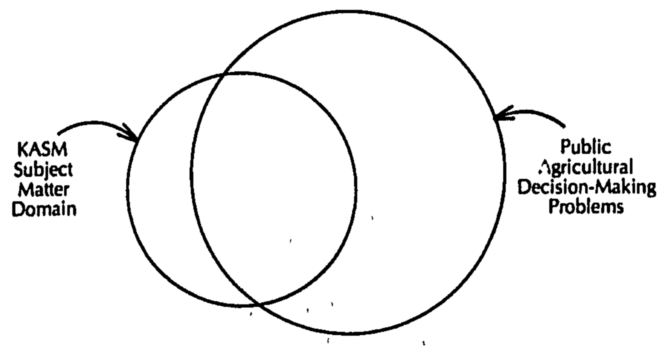

FIG. 37. The subject-matter domain of the Korean agricultural sector model relative to public agricultural decision-making problems: partially relevant.

System of Models

Each component of KASM is a model of one of five subsystems of the agricultural sector — population, national economy, demand, resource allocation and production, and technology change. Each of these models may be used alone or in combination with one or more of the others, depending on the requirements of the particular analysis at hand. In many cases, a partial analysis is not only sufficient for the problem at hand but may also be necessary to limit the range of options to be tested, the complexity of interactions, and the volume of output to be analyzed.

A key factor in the usefulness and, hence credibility of actual applications of KASM is the model's comprehensibility to the user. Often, at lower decision-making levels, not only are partial analyses sufficient, but more comprehensive analysis would be confusing and, hence, unfeasible, given the partial view of the world institutionally mandated at those levels. To paraphrase one Korean analyst working in the Ministry of Agriculture and Fisheries, each official sees no farther than the boundaries of the square of floor tile under his chair.

Even the use of KASM for partial analysis, however, results in a more comprehensive view because of KASM's very nature as a *system* of models. Even if only one or two of its components are used in a particular application, a look at Figure 16 in chapter 5 will immediately identify which of its inputs come from which other components of the system and which of its outputs affect which other components. In addition, considering the component as part of a larger system will help ensure consistency in defining and interpreting input and output data.

Of course, higher decision-making levels require more comprehensive analyses, in which case more or all of KASM can be used. Viewing and using KASM as a system of models greatly increase its flexibility and usefulness in various kinds of decision analyses.

Decision Entry Points

A decision entry point is a place in the model where a user — i.e., an analyst or a decision maker — may make a specific assumption relating to a particular decision analysis. Flexibility is provided in the use of KASM through the selection of components to be used. Far greater flexibility and versatility can be obtained, however, through the ingenuity and creativity of the user himself. A great many decision entry points are explicitly built into the KASM components. In addition, however, a great many others are implicit in the constraints, structural assumptions, and parameter values — any of which may be changed by the user to reflect the effects of alternative decisions. Through the user's ingenuity and creativity, combined with his technical familiarity with KASM and the Korean agricultural sector, the decision applications or combinations of explicit and implicit decision entry points can be innumerable. Rather than trying to present an exhaustive list of the decision entry points of each KASM component, many of which have already been described in preceding chapters, illustrations of their use are provided in the next two sections and in the following chapter.

USE OF *KASM* IN INTERACTIVE PROBLEM-SOLVING ANALYSIS

Chapter 2 describes the decision-making process as highly iterative and interactive and as composed of six functions (Figure 8, chapter 2). These functions are problem definition, observation, analysis-synthesis, decision, action, and responsibility bearing.

Iteration takes place throughout the process and is continuous over time in that the evaluation of the consequences of implementing one decision can indicate resulting problems that also require action on the part of decision makers. Interaction is also an essential and integral characteristic of the decision-making process. Decision makers do not act in a vacuum. Of necessity they interact with executives responsible for carrying out their decisions, with affected parties who provide feedback for evaluating decision consequences and for identifying new problem situations as they arise, and with investigators and analysts responsible for gathering information and analyzing the possible consequences of alternative courses of action. In using KASM for decision analysis, close interaction between investigators and decision makers is of key importance. In applications of the model to date, this interaction has proven invaluable not only for defining the decision runs to be made and interpreting the results but also in improving model structure and data input.

It is in the analysis-synthesis function of the decision-making process that KASM makes its direct contribution, along with other formal and informal models, as part of a problem-oriented model. Beyond that, however, through the interactive iterations inherent in the process, the model also provides information for modifying and refining the problem definition, which gives guidelines for data collection.

The remainder of this section discusses how KASM is used as part of a problem-oriented model for problem-solving analysis. For illustrative purposes, brief reference is made to the land and water development analysis reported in more detail in the next chapter.

Problem Definition

It is very important for the analyst to view the decision-making process from the perspective of the decision maker. Decision makers perceive unsatisfactory conditions in the portion of the real world related to their office (their piece of floor tile — the larger circle in Figure 36) and are faced with having to decide on a course of action to improve the perceived situation. Any use of KASM in the analysis of such problems, indeed the decision of whether and how KASM should be used, must be based on the analytical requirements of the specific problem. That is, the use of any given model for decision analysis should depend on the problem definition, not vice versa.

The problem definition, then, starts with the recognition that there is a real-world situation to be improved. In our land and water development illustration, the situation is that Korea is a land-short country trying to provide an adequate diet for its growing population, while at the same time, for economic and national security reasons, it is trying to reduce foreign exchange costs of food imports. As Korean officials prepared the Fourth Five-Year Economic Development Plan for 1977–81, important questions arose concerning investment priorities. Given the investment requirements of other sectors of society, what mix of programs in agriculture would best ensure an adequate diet and achieve self-sufficiency in the major food staples at the lowest possible investment cost? What would be the effect on food prices and, hence, inflation and farm income?

These questions led naturally to the next steps in the definition of the problem: selection of performance criteria and identification of decision instruments. What measures of the real world should be used to evaluate the consequences of decisions taken to improve the situation? What decision-making options are available? In our illustrative situation, through interaction with decision makers in the Ministry of Agriculture and Fisheries (MAF) and in its Agricultural Development Corporation (ADC is responsible for carrying out land and water development projects in Korea), it was decided to analyze the effects on food production, nutrition, and agricultural imports and exports and foreign exchange requirements of alternative levels and patterns of investment in various land and water development programs.[1]

Although the immediate decisions to be made were in the context of the 1977–81 Fourth Five-Year Plan, the full potential of many land and water development programs take many years to be realized. Therefore, it was decided to look at the 25-year period to the year 2001.

Decision Analysis

In the analysis stage, a problem-oriented model is defined, put together, and used to project the likely consequences of alternative courses of action. In defining and constructing the problem-oriented model, a combination of art and science is required of the analysts, as described in chapter 4. The analyst must know what formal models are available that can provide information required to analyze the problem at hand. The art is in recognizing where and how a formal model, such as KASM, can be used. Whether KASM, in whole or in part, can be used in a particular problem-solving analysis depends to a large extent on the creativity and ingenuity, as well as the technical competence, of the analyst in making special assumptions, changing the model structure, and generally molding the model to fit the requirements of the problem definition. This includes molding it to fit into the larger structure of the problem-oriented model, which also incorporates other formal models to provide other kinds of information beyond the scope of KASM. Where formal models do not exist or cannot be specially built, informal components (mental, verbal, diagrammatic, etc.) are used to round out the problem-oriented model.

The problem-oriented model used in the land and water development analysis was composed of KASM components, another formal model (a polyperiod linear program) specifically built for this analysis, and informal components that made exogenous projections required as inputs to the formal, computerized components and that provided other information for the analysis. The KASM components used were the demand, resource allocation and production, population, and accounting components. In place of the technology change component, which was still in a preliminary testing stage at the time of the analysis, the polyperiod linear program model was used to project the quality and quantity of the land base resulting from investments in the various land and water development programs and the yield effect of those programs. Basic yield projections depending on biological improvements, and input application rates were projected informally, based on information from Korean crop researchers and government officials.

KASM was not taken as a given, fixed model when used in the analysis. Rather, it was changed wherever the analysts felt a change was necessary to meet the requirements of the problem-oriented model. Specifically, price assumptions were changed in the demand component for barley and wheat; some constraint equations in the resource allocation component were dropped and replaced with others, and special assumptions were made limiting the future expansion of land in nongrain crops; and the definitions of some accounting variables, particularly self-sufficiency percentages, were changed.

Once the problem-oriented model was defined and constructed, an experimental design process specified the alternative decision assumptions to be investigated with the model and the primary performance variables to be observed. The alternative decisions were in terms of investment budgets to be spread over time for specific programs including deland reclamation, paddy field consolidation, drainage, large-scale irri-ation, and upland development. The polyperiod linear program model 'as used to determine for each alternative budget level the optimum istribution over these two dimensions and the resulting projections of ase and yield levels, which were in turn provided as input to KASM.

It was very important to preselect the output variables of primary iterest. A simulation model such as KASM can generate a great quantity of iformation about a large number of variables. Unless the analysts re-:ricted themselves to only those measures of performance most relevant to ie analysis, they, and particularly the decision makers, would only be onfused by the mass of data. Main performance criteria for the land and 'ater development analysis included production levels by commodity, elf-sufficiency percentages by commodity, import and export quantities y commodity, and foreign exchange requirements for each of several evels of development investment.

Analysis of the results of the decision runs by the analysts and decision iakers led to further iterations respecifying the experimental design, mod-'ying the model, and even revising the problem definition. One example f many such instances in the land and water development analysis oc-urred when high officials in the Ministry of Agriculture and Fisheries uestioned the self-sufficiency projections. Investigation revealed that :ASM did not define self-sufficiency in the same way as did MAF, and ierefore its definition in KASM was changed.

These iterative interactions among the model, analysts, and decision iakers, as well as with executives and affected parties, ultimately con-erge on prescriptions for decision. The land and water development nalysis provided information that was used in negotiations between MAF nd the Economic Planning Board for land and water development invest-nent capital in the Fourth Five-Year Plan.

:redibility

Throughout the process of defining, constructing, and using a roblem-oriented model, the model is continually tested for credibility and nodified and refined as necessary until sufficient credibility is achieved vith decision makers for its information to be used in decision making. Of ey importance with respect to a problem-oriented model is its credibility n the eyes of decision makers, and a necessary but insufficient condition or that is its credibility in the eyes of the analysts.

As discussed in chapter 2, there are four essential tests a problem-riented model must pass for decision-making credibility. These tests are:

1. *Coherence*. The model is checked for internal logical consistency, abstracted from its real-world referent.

2. *Correspondence.* The behavior and structure of the model are compared with actual and expected behavior and structure of its real-world referent.
3. *Clarity.* The model must be not only unambiguous but also comprehensible both to decision makers and analysts.
4. *Workability.* The model is assessed on the basis of how well its prescriptions work out when implemented in the real world.

KASM and its components have been subjected to each of the four tests. The components have been tested individually and in combination, as reported in the preceding chapters. Coherence tests take place as part of the debugging process of individual components. Correspondence testing of KASM is an iterative process wherein components are tested individually and in various combinations against knowledge of the real-world referent and then are retested continually as new knowledge is gained. In the specific case of the land and water development analysis, coherence and correspondence tests were rechecked for KASM with the modifications made for the specific analysis. In addition, such tests were also carried out and modifications were made in the other portions of the problem-oriented model until both the analysts and the decision makers were satisfied with the results.

Clarity and workability tests are most important whenever models are used for decision analysis. Korean decision makers and investigators understand the models more and more each time they use them. Similarly, the models become easier to use and interpret as familiarity increases. Workability tests are passed as decisions are implemented with positive results. The land and water development analysis results played an important role in determining planned investment levels for land and water development programs in the Fourth Five-Year Economic Development Plan. A more detailed description of the land and water development analysis is presented in the following chapter.

KASM AND ANALYSIS FOR THE FOURTH FIVE-YEAR PLAN

The setting within which the Korean five-year planning activity occurs is conducive to model application. Three needs are uppermost in the minds of those developing the plan: (1) the time frame imposed upon them, (2) the volume of statistical data that must be considered in both a retrospective and a projective sense, and (3) the consistency that should bind different segments of the plan into a cohesive whole. In all three cases, a generalized simulation model, already in place, holds considerable promise for those charged with actual plan development.

Therefore, as the Fourth Five-Year Plan was being developed, it was natural for those in the Ministry of Agriculture and Fisheries (MAF) to turn to KASM for analytical assistance. Fortunately, there was sufficient flexibility that the existing models could be used as already constructed, coefficients could be changed to reflect alternative growth assumptions, or individual components of KASM could be used as needed for particular analyses.

Livestock Planning

Working relationships had earlier been established with MAF officials responsible for livestock planning, and a rudimentary, specialized model had already been used in making mid-period projections during the Third Five-Year Plan period. Working relationships and model appreciation had been further kindled by seminars within the ministry and frequent contacts between MAF Livestock Bureau personnel and personnel from the National Agricultural Economics Research Institute (NAERI)/Korean Agricultural Sector Study (KASS), and the Korean Agricultural Planning Project (KAPP). Thus, once the outlines of the fourth plan became known, a request for assistance with the analysis quickly followed from the Livestock Bureau.

The overriding livestock policy objective as defined by MAF at that time was to reduce imports of feed grains as a way of conserving scarce foreign exchange. Subsidiary and conflicting objectives were to meet consumer demands for livestock and poultry products and to do so without undue increases in consumer prices. Additional information was sought on the specific effects of alternative techniques for restraining growth — taxes on imported feed stuffs, taxes on livestock per se, or other disincentives.

To accomplish the analysis, an informal working group was established composed of members of the Livestock Bureau, NAERI/KASS, and KAPP. Interchange followed on objectives, on alternative assumptions needed for the analysis, and on input-output coefficients and prices. The exchange was beneficial to both modelers and decision makers: data requirements and constraining growth assumptions of the modeling effort forced ministry personnel to rethink programs for feasibility and consistency, and their responses forced the model to be adapted to meet policy needs more realistically. An additional bonus for all future analysis was the opportunity to improve and update the data and structural assumptions for the model.

Although the initial request from the ministry was for only one set of projections, further discussion led to the inclusion of several alternatives. The final results included a base run that was approximately the natural growth rate without policy interventions and two alternatives that exogenously restricted the rate of growth of swine and poultry, the major consumers of feed grain. Impacts were estimated for (1) livestock and poultry numbers; (2) real consumer prices for meat, milk, and eggs; (3) per capita consumption of these commodities; and (4) total feed requirements for the livestock sector.

The alternatives thus analyzed and refined by discussions with the Livestock Bureau became the basis for the policy targets in the Fourth Five-Year Plan. MAF was unable to choose a target plan that achieved the directive of reduced growth in feed grain imports with minimum disruption of the consumer market for meats. At the request of the Livestock Bureau, later analyses were conducted on specific programs to achieve those targets.

Population Planning

Crucial to any national planning activity are reliable estimates of total population growth and its characteristics. Early in the KASM work, a cohort-survival population model was developed (chapter 6) to project total, farm, and nonfarm population; off-farm migration rates; agricultural labor supply; and certain population and labor force characteristics. Projections from this component are used in KASM as one of the bases for projection of food and the availability of manpower for agriculture.

At an early stage in the development of the MAF Fourth Five-Year Plan it became necessary to decide upon a consistent set of population projections. Such projections were available from the MAF Statistics Bureau and from KASM, or the ministry could decide to generate others. After due consideration and a discussion at a seminar attended by representatives of all MAF bureaus the KASM projections were chosen. The rationale as given by the director of the MAF Planning Bureau was that the underlying theory and assumptions of KASM more closely resembled reality than did those of other available projections and would be better than any others that could be produced on short notice by the ministry.

Accepting these projections essentially meant that farm and nonfarm food consumption projections in the plan would be a function of KASM population projections. Further, farm labor force estimates from the model would underlie planning for mechanization and wage rates in the farm sector.

In this case, anticipation of a planning need, having a model on hand capable of generating information to fill that need, and user confidence in the results led to a direct contribution to a vital ministry program. Moreover, acceptance and wider use of the models came with favorable experiences by those in middle-management positions within MAF.

Foreign Trade

Another example of the use of KASM in analysis for the Fourth Five-Year Plan was in assessing the export potential of Korean agricultural commodities. In 1974 a MAF committee was assigned the task of determining which commodities might best be developed for export, to where, and in what quantities. A request for KASM assistance followed.

The demand-price-foreign trade component uses a set of demand equations to estimate domestic consumption and, when linked with the resource allocation and production component, provides estimates of an exportable surplus and/or import requirements. Commodity prices serve to link (1) domestic demand and supply and (2) the domestic agricultural sector with the world economy.

To address the problem posed in the Fourth Five-Year Plan required projections of world supply prices for comparison with projected Korean supply prices. Relatively lower domestic prices projected for the period of the upcoming Five-Year Plan suggested an export potential for certain commodities. Information was provided under the assumption of constant real 1974 prices and alternative relative changes from 1974. The 19 commodity groupings of the model proved a handicap, since export planning was in terms of individual commodities. Model results did provide indications, however, for the major commodities and for groupings of others. Basically, the information provided from this analysis served in this instance to check consistency and to confirm conclusions already formed by the committee.

Grain Consumption

In the early 1970s, the Korean government strove to reduce rice consumption in favor of barley and wheat in order to reduce foreign exchange costs of grain imports, rice being the most expensive of the three grains on the world market. Measures used included increased government involvement in grain markets, high rice prices, wheat flour subsidies, a dual price system for barley, requiring government rice to be mixed with barley before sale, enforcing riceless days in public eating establishments, decreasing the milling rate, and public exhortation of consumers to shift consumption from rice toward wheat and barley. Other, sometimes competing, objectives of these measures were to increase farm income, to encourage rice and barley production, to hold down inflation, and to reduce deficits in government grain management accounts.

As work on the Fourth Five-Year Plan got underway in 1975, however, the success of the above policies (as well as past successes in crop improvement research and extension programs) gave Korea a sense of security that rice and barley self-sufficiency had been attained and gave rise to expectations that there would be surpluses in those two grains over the next plan period (1977–81). The questions now were, what grain consumption patterns could be expected over the plan period and what could the government do now to encourage consumption of rice rather than wheat, since wheat was expected to be the only imported food grain during the plan period (apart from pulses, which are also considered a food grain in Korea)?

Several analyses were made with the KASM demand component to assess consequences of alternative projected price patterns for rice, barley, and wheat. The analysis indicated that keeping real rice prices constant, phasing out the dual price for barley, and removing the wheat subsidy could result in increased rice consumption, reduced wheat consumption, and limited surpluses of rice and barley.

By mid-1977 further evidence of fundamental change in several aspects of the agricultural and general economic system became clear. With the high price policy for rice and the administrative controls on rice consumption, such as the mixing of barley with rice, riceless days, and restrictions on the size of the rice bowl in restaurants, rice stocks were mounting. Government costs of maintaining the high price policy and of rice storage were increasing with an accumulated deficit in the government grain management special account of more than $600 million. This deficit, in addition to the projected surplus in the foreign trade accounts, was expected to exert unacceptable inflationary pressure on the Korean economy. Thus additional analysis and reconsideration of the rice price and consumption policies became necessary.

KASM was used to make projections of four alternative assumptions about rice prices and consumption policies. Specifically, since the focus of the analysis was on only one commodity and on only the consumption of that commodity, only the DEMAND model of KASM was used for this partial analysis, together with independent production and population projections.

Assumptions and Policy Alternatives. Although attention focused on rice, DEMAND incorporates interactions among commodities — as they substitute for one another and compete for a given consumption budget — as prices and income change over time. Therefore, independent production projections were made for each commodity considered in DEMAND consistent with targets of the Fourth Five-Year Development Plan.

Population projections were based on results of KASM's population model consistent with the Fourth Five-Year Development Plan targets for 1981. The Production Bureau, MAF, estimated rice production in 1977 to be 3.5 per cent above the 1976 harvest. Beyond that, it expected rice yields to increase at an average rate of 1.5 per cent per year through 1981 and 1.0 per cent annually thereafter. Changes in land area devoted to rice were expected to be negligible with an assumed total increase of 0.5 per cent spread over the ten-year period of the analysis, 1976–86. The resulting projection of rice production showed an average annual increase of 1.51 per cent.

Given these population and rice production projections, the following four alternative policy assumptions about rice consumption were investigated:

ALTERNATIVE 1

a. Real consumer and producer prices of rice, barley, and wheat remain constant at 1976 levels through 1986.
b. The desired carry-out stock level of rice (held by the government, at seaports, and in farm and urban households at the end of the rice year) is 750,000 metric tons. This is about twice the levels actually carried over each year during the early 1970s and about 75 per cent of the level carried out in 1975.
c. Government-imposed restraints on rice consumption are maintained at 1977 levels through 1986. Economic Planning Board and MAF estimates indicate that these restrictions amounted to over 400,000 metric tons of rice in 1975, not counting restrictions on the use of rice in alcoholic beverages, and more than 600,000 metric tons if alcoholic beverages are included. Assuming, for simplicity, that all the restrictions apply only to the nonfarm population, these amounts translate into 20 kg/capita and 30 kg/capita, respectively.

ALTERNATIVE 2

a. Same as "a" in alternative 1.
b. Same as "b" in alternative 1.
c. Government restrictions on rice consumption, in the amount of 20 kg/capita for nonfarm consumers, are gradually phased out over the four-year period 1977–80. That is, 5 kg worth of restrictions are removed in each of the four years. Restrictions on the use of rice in alcoholic beverages remain in effect.

ALTERNATIVE 3

a. Real consumer prices of rice, barley, and wheat are determined in the market, beginning in 1977, by excess demand conditions, subject to the constraints that (1) rice and barley prices will not be allowed to rise more than 10 per cent per year or to fall more than 5 per cent per year in real terms, and (2) wheat will be free traded, so that its consumer price will not rise above the import price plus a marketing margin. (Producer prices of rice, barley, and wheat are tied to consumer prices with a constant proportional marketing margin.) In addition, the producer price of rice will not be allowed to rise above the 1976 level in real terms.

b. Same as "b" in alternative 1.
c. Same as "c" in alternative 2.

ALTERNATIVE 4

a. Same as "a" in alternative 3.
b. The desired carry-out stock level of rice held by government, at seaports, and in farm and urban households will be 2 million metric tons beginning in 1977. This represents a policy of maintaining emergency reserves.
c. All government restrictions on rice consumption, i.e., 30 kg/capita for nonfarm consumers, are removed over the 1977–81 period.

Alternative 1 represents continuation of present policies and, therefore, is taken as the base run against which the other alternatives are compared.

Simulation Results and Conclusions. Of the hundreds of variables of KASM, our attention was focused on only four — nonfarm per capita rice consumption, rice self-sufficiency, consumer price of rice, and carry-out rice stocks.

The relative results of the four variables for the four alternatives are plotted over time as indexes in Figures 38-41. In Figures 38, 39, and 40, the levels of carry-out rice stocks, nonfarm per capita rice consumption,[2] and consumer price of rice respectively are indexed to initial (1976) levels. Since self-sufficiency is normally expressed as a percentage, and 100 per cent self-sufficiency is generally used as a reference point anyway, that percentage, rather than an index, is plotted directly in Figure 41.

In alternative 1, the base run, rice stock levels increase to about 4⅓ times the 1976 level (Fig. 38), or almost 5.7 million metric tons. This results from surplus production (Fig. 41) at the high, constant real price (Fig. 40) going into stock.[3] Even after removing most of the restrictions on rice consumption (alt. 2), stocks still almost triple by 1986 (Fig. 38), staying at about 65 per cent of base-run stock levels.

It is only when the market price is allowed to respond to the surpluses and large inventories (alts. 3 and 4) that stock levels remain at reasonable levels. The surpluses cause prices to fall[4] (Fig. 40), which in turn causes consumption to rise above levels in alternatives 1 and 2 (Fig. 39). Under alternative 3, stock levels stabilize around 2.1 million metric tons, about 65 per cent above 1976 levels (Fig. 38), which is less than 40 per cent of the base-run result by 1986. Also, nonfarm per capita consumption stays slightly above base-run levels (Fig. 39), and overall rice self-sufficiency remains in balance at about 100 per cent after 1981 (Fig. 41).

Consumer rice price under alternative 4 also falls (Fig. 40), except for two years (1980 and 1981) when the price increases because of the combined effects of (1) the greater removal of consumption restrictions assumed, and (2) the higher level (2 million metric tons) of desired rice stocks. Therefore, after 1980 the consumer price is higher than under alternative 3 (Fig. 40) and consumption is consequently lower (Fig. 39), causing self-sufficiency to stabilize at about 102 per cent instead of 100 per cent (Fig. 41) and stock levels to increase above those of alternative 3 (Fig. 38).

Figure 41 shows that, for two or three years under both alternative 3 and alternative 4, self-sufficiency falls below 100 per cent before recovering with the secular decline in consumption. No rice imports are required, however, since the deficits are made up from the surplus stocks.

This analysis did not consider possible rice supply responses to the falling price. Other analyses have indicated that any supply response would come from yield responses rather than any significant change in land allocations. Further analysis incorporating a supply response would be necessary to determine whether nonfarm demand or supply has the greater response and the consequences on stock levels and self-sufficiency. It is possible, depending on the strength of the supply response, that real prices would stabilize, in the short run, at a level below the 1976 level rather than continue to fall. In the long run, however, as consumption falls, prices would resume their downward trend unless alternative uses of rice-producing resources were encouraged.

Figure 39 indicates that rice consumption begins a general downward trend after about 1983 in the base run. This turning point is advanced by about two years under the other three alternatives because of the more rapidly rising consumption in the late 1970s. Such behavior is a result of the assumption in the DEMAND model of KASM that beginning in the early 1980s Korea will follow Japan's pattern of long-run declining rice consumption. Further analysis would be necessary, if desired, to investigate the effect on these four alternative policy sets of assuming a later turning point or possibly even no turning point during the period of the analysis.

The results of the four alternative rice price and consumption policy runs indicate that, even under conservative projections of rice production, a continuation of present real price levels for rice and government-imposed rice consumption restrictions would result in surpluses that would amount to more than a quadrupling of rice stocks by 1986. Even if most of the consumption restrictions were removed, the 1976 stock level would still almost triple by 1986.

Although further analysis would be required to incorporate a supply response, the indications are that surpluses can be reduced by allowing the rice price to fall in real terms while at the same time removing consumption restrictions. The resulting double boost to consumption would stabilize stock levels at about 75 per cent above present levels, with self-sufficiency at or slightly above 100 per cent.

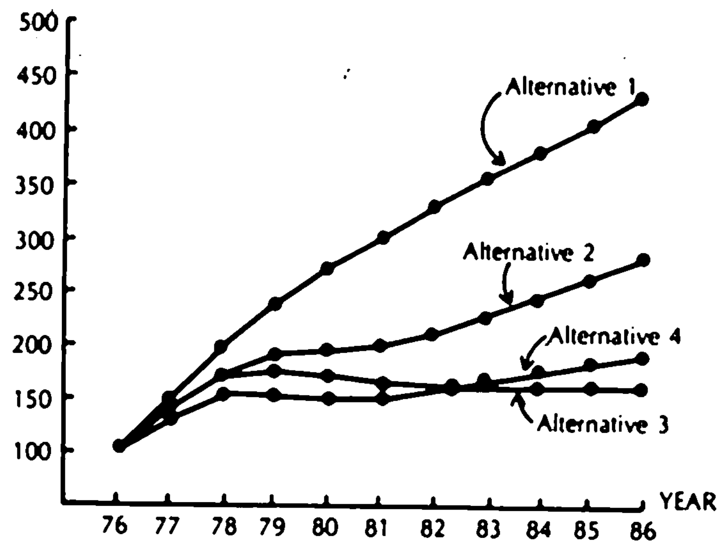

FIG. 38. Index of carry-out rice stock level, 1976-86, under four alternatives (1976 = 100).

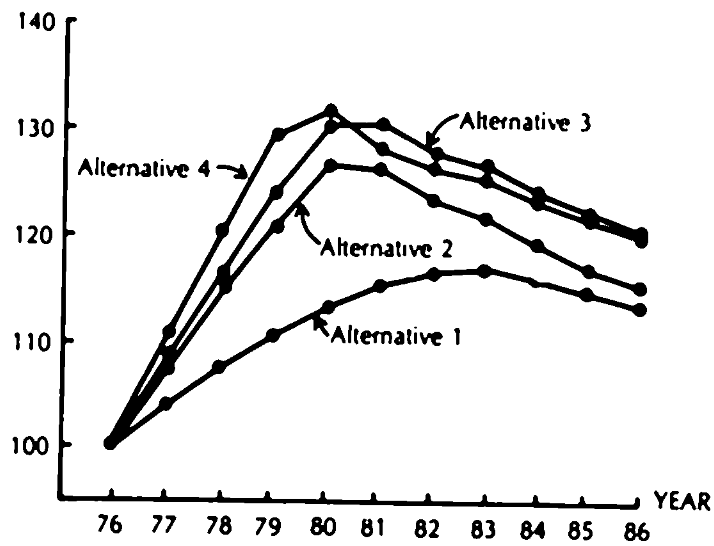

FIG. 39. Index of nonfarm per capita rice consumption, 1976-86, under four alternatives (1976 = 100).

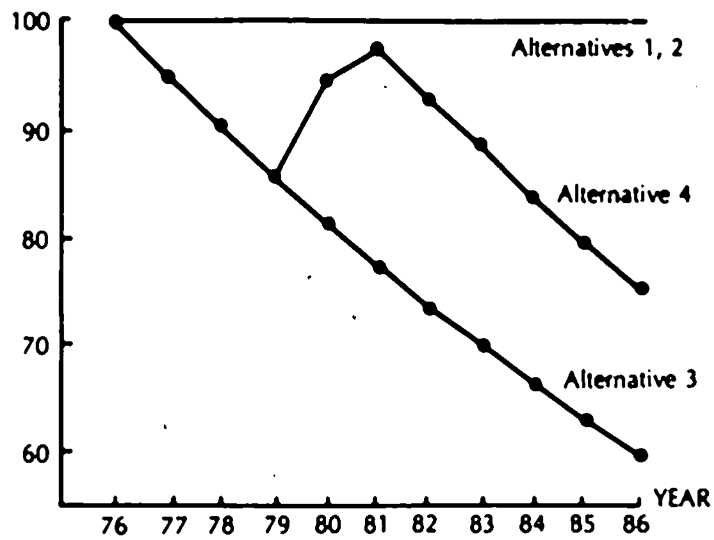

FIG. 40. Index of consumer price of rice, 1976-86, under four alternatives (1976 = 100).

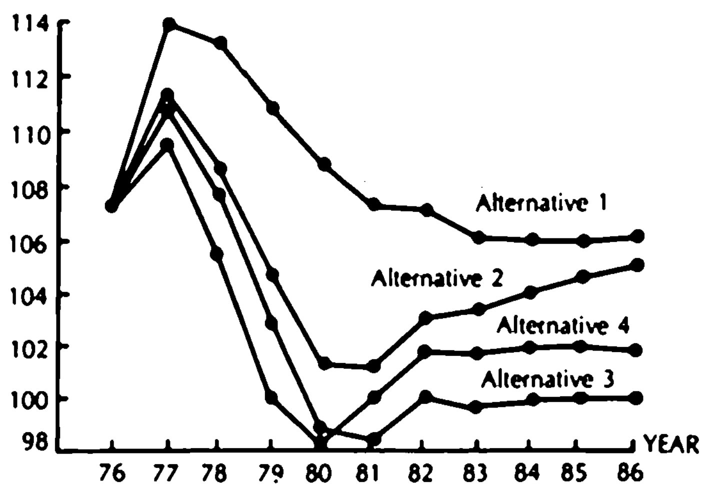

FIG. 41. Percentage of rice self-sufficiency, 1976-86, under four alternatives.

The Korean government removed the wheat flour subsidy, increased the sales proportion of pure rice relative to rice mixed with barley, and developed plans to phase out the dual price system on barley. Although it was impossible to discern what direct influence, if any, the KASM results had on these decisions, the simulation results at least provided strong confirmation of information coming from other sources.

CONCLUSIONS

From the foregoing discussion in this and preceding chapters, we can draw conclusions concerning (1) use of subject-oriented models in general and of KASM in particular, and (2) areas for further development of KASM and its theoretical foundations.

Use

First and foremost, any formal model should be used with great caution, and KASM is no exception. KASM can be a powerful analytical tool for public agricultural decision making in Korea. It can be used to investigate complex decision options more reliably than can informal or simpler formal models. Nevertheless, erroneous conclusions can easily be drawn from simulation results unless analysts and decision makers alike take care to understand, by tracing through the model's data and causal structure, what gives rise to those results. Wrong decisions can be made on the basis of wrong explanations of projected responses to alternative decision assumptions.

Furthermore, KASM or any single model, formal or informal, must not be relied upon as the sole source of information for complex public decision making. No single model can possibly provide all the information necessary — economic, social, political, military, administrative, short-term, long-term, normative, nonnormative, and so forth. That is, every problem-oriented model for public agricultural decision analysis will of necessity be composed of multiple formal and informal models.

Fortunately, the decision-making system in the Korean Ministry of Agriculture and Fisheries reduces the chances of making these errors — but it does not eliminate them. Middle-level officials of MAF insist on fully understanding the basis of analyses providing information to their decision making. In this way they prepare themselves to be able to answer any questions their superiors may ask when proposed plans and programs are presented for approval. Similarly, higher-level officials need to be well versed in the analytical basis of decisions (and therefore ask the questions of lower-level officials) in order to back up their negotiations with other ministries for funding and cooperation. These demands of the decision makers at all levels of the ministry place a great responsibility on the modelers and analysts to find ways to explain the models and interpret their results in terms decision makers can understand — essential if the models are to pass the clarity test for credibility.

Another conclusion we can make regarding use of KASM is that it can either be a very flexible system of models applicable to a very wide range of decision analyses or a rigid, specialized model of limited application. Which it is depends on the technical knowledge of the analysts with respect to the model, the Korean agricultural sector, and the problem-solving needs of decision makers. Also important in determining the flexibility of the model and, hence, its utility is imagination and ingenuity on the part of the analysts in artfully selecting and linking components, making special assumptions, and changing data to suit the needs of a particular analysis.

Finally, we must emphasize two characteristics of the model's outputs and use. First, it is much more useful and valid to compare results of alternative decision runs with each other and with a base run than to look at the absolute projections of any one run. KASM, designed for medium- to long-term projections and analysis, and using sometimes questionable data, cannot and should not be relied upon as a forecasting model. However, a great deal of useful information can be obtained on the likely *relative* consequences of following alternative courses of action.

Second, whenever several KASM components are run together, behavioral consistency is ensured among the various subsectors included. In addition, any inconsistencies among policies and programs particular to the various subsectors will show up in model outputs in more comprehensive analyses. Thus, although KASM components can be run singly for analysis of decisions at lower levels in the ministry, combining components for higher-level decision analyses will indicate the significant indirect effects of government actions taken in one subsector on another.

Development

Several conclusions can be drawn relative to further development of the KASS system of models. Most important is the general responsibility of the modelers and analysts maintaining and using KASM for decision analysis to keep abreast of changes in the problem set relevant to Korea's public agricultural decision makers (the larger circle in Figure 37) so that KASM can be modified to keep the portion of its subject-matter domain lying outside that relevant problem set (as in Figure 37) as small and unimportant as possible. This requirement emphasizes the importance of close cooperation and interaction between Korean analysts and decision makers not only for use of the models for decision analysis but also for continual model development.

Specific development areas can be identified in addition to the improvements in existing components indicated in the preceding chapters.

Marketing. Recently, MAF has been giving increasing attention to the marketing of agricultural inputs and products. High losses in the 1975 rice crop in some areas of the country were attributed to untimely and inadequate distributions of pesticides to insect-infested areas. On the product side, increased consideration is being given to marketing improvements to curb price rises and reduce commodity losses. In addition, questions are being raised about the effect on production patterns of the transportation and marketing opportunities opening up with the expansion of the highway system into rural areas. Currently, KASM touches product marketing only with price margins and loss rates and input marketing not at all. The marketing of agricultural inputs and products appears to be a fruitful area for further modeling.

Livestock. As useful as KASM was for the livestock analysis for the Fourth Five-Year Plan, it became apparent that the handling of the livestock subsector as part of the resource allocation and production component was inadequate, both (1) as a representation of private sector sales, feeding, and investment decisions, and (2) in its exclusion of many of the important government policy instruments influencing the livestock/feed subsector. Preliminary conceptualization has begun in Korea of a set of livestock models, drawing on experiences elsewhere [68, 144], that incorporates demographic characteristics, investment decisions, sales rates, feeding rates, and the effect of feed prices and supplies. Such models should also include government credit and subsidy programs, feed and price policies, and pasture improvement programs.

Investment. Any model is based on the state of the theoretical and methodological art. Advances in investment/disinvestment/user cost theory [17] will contribute greatly to the ability of KASM to simulate agrarian change, capital formation, and growth in the agricultural sector. Some of the most important issues facing Korean public agricultural decision makers are related to investment, and KASM is currently inadequate to address many of them.

Disaggregation. KASM has several aggregation error problems. One of the most important is in the resource allocation and production component, where local and regional differences in resource endowments, access to markets, and commodity specialization are obliterated in a national objective function and a national aggregation. The model was originally designed for three regions [151] but was later aggregated because of the difficulty of obtaining regional data and to reduce the costs of model development in other, higher-priority areas. At some point it may be useful to consider generalization of the model to handle disaggregation flexibly, not only in the spatial dimension but also by income class in the farm and nonfarm sectors, and to facilitate redefinition of the current commodity groupings and the national economy sector aggregations.

Data System. Flexible disaggregations such as those suggested above would put great demands on the data system supplying the model. A long-run development objective should be to design and implement a data management system that would transform data from the form collected and compiled at local, county, provincial, and national levels into the form required by KASM. Such a data system would not only facilitate flexible disaggregations but would also facilitate keeping data in the model up to date as new statistics and other information become available.

Tuning. As we have seen in earlier chapters, it is often difficult or impossible to estimate model parameters from recorded data series. In some cases, parameters are "estimated" by manually tuning the model to track-recorded time series. This process can be greatly improved by applying to KASM optimization packages [26] designed to find values for key parameters that optimize the model's "fit" to recorded time series.

Ease of Use. Finally, the ease with which KASM can be used by decision makers, and hence its credibility, can be increased with the use of a conversational, interactive language to interface the user with the model. Such a language has been developed [171, 178, 180] that enables the user to interact with the model to change data, make decision assumptions, and make decision runs.

13
KOREA'S LAND AND WATER DEVELOPMENT POLICY ALTERNATIVES

Richard D. Duvick

INTRODUCTION

Korea is a land-short country that continues to face the problem of providing adequate food for its population. In 1974, a population of 34.7 million people was dependent on a cropland base o' only 2.238 million hectares, or approximately .064 hectares per person. Population growth averaged about 1.8 per cent per year between 1970 and 1975 and is expected to grow at an annual rate of 1.6 per cent per year from 1975 to 1985. Net loss of cropland to nonfarm uses has been 12,000 to 15,000 hectares per year. All of these factors put added pressure on the need to increase both agricultural productivity and the quality and quantity of the agricultural land base.

Rice and other grains have traditionally been the major foodstuffs in the Korean diet. A major policy goal of the Korean government has thus been to become self-sufficient in rice and to improve or maintain the self-sufficiency of all other food grains: mainly barley, wheat, pulses, and potatoes. Various means are available to increase production at a faster rate than consumption and, hence, to improve these self-sufficiency percentages. Better seed varieties and improved cultural practices can increase production. Likewise, lower milling rates, riceless days, and other administrative measures that cause changes in the diet can reduce consumption. But another area that has received, and will continue to receive, great attention in Korea is land and water development, which involves improving the land base through irrigation, drainage, and consolidation projects and increasing the land base through reclamation.

The major purpose of the research reported in this chapter was to evaluate various alternatives for the future development of Korea's land and water resources in light of the future food needs of the country. Since many development projects require a number of years before their full potential is reached, the analysis examines the 25-year period to the year 2001.

PROCEDURE

The first requirement was to gather data on various aspects of land and water development. Since detailed data by region either were unavailable or too costly to acquire, given the time and resources available, it was decided to evaluate development on a national basis only. Two basic categories of land and water development activities were defined:

1. *Improvement of the present land base:* irrigation, drainage, and land consolidation to improve the quality of cropland and increase its productivity (see Table 10 for a summary of the basic effects)
2. *Additions to the present land base:* reclamation of tidal land for paddyland and conversion of idle and forested slopeland to cultivated upland to increase the quantity of cropland

In keeping with this basic framework, the area of potential land for each type of development activity was determined. At the same time each type of development activity, such as irrigation, was subdivided into three cost classes — low, medium, and high cost of development. Specific estimates were also made of the effect of each type of development on crop yields and cropping intensity, in line with the framework suggested in Table 10.

This provided the primary data necessary to develop a polyperiod linear programming (LP) model. The LP model selected land and water development activities by type and cost class that would maximize the total production of food grains over the 1977–2001 period, subject to investment and other constraints defined for various alternatives. Output of the model included the amount of each activity to develop by time period (e.g., hectares of low-cost irrigation to develop in 1977–81), total hectares of paddy- and upland, yields of rice and the other food grains, and double-crop ratios resulting from the combination of activities developed. Thus the LP model not only selected the mix of activities and period for development, but provided measures of the combined effects of these activities on future yields, hectarage of cropland, and land-use intensity.

These data were then used to modify the basic input data on yields, changes in paddy- and upland, and double-crop ratios within the Korean Agricultural Sector Model (KASM) resource allocation and production component (RAP). Outputs of KASM, using a combination of RAP and the demand component, were then used to compare and analyze the effect of

TABLE 10
Theoretical Basis of Benefit for Land and Water Improvement Activity

Crop	Irrigation	Surface Drainage	Subsurface Drainage	Land Consolidation
Rice	Increases average yield by improved water management Allows higher average yield to be achieved through use of high-yielding varieties Creates additional paddyland	Increases average yield by prevention of flood damage	Increases average yield by a Improvement of soil structure b Removal of harmful salts c. Better aeration of root zone d. Allowing more high-yielding variety rice to be grown	Increases average yield by a Improved water management b Improved drainage c. B ter roads to promote increased use of inputs such as fertilizer, lime, and insecticides d Allowing more high-yielding variety rice to be grown Average yield is decreased because of loss of land for roads, canals, etc.
Second Crop	Allows additional double-cropping because of improved water control and drainage	No effect	Allows double-cropping, since adequate drainage of subsoil water improves the chances of getting into the field on time	Allows additional double-cropping because of improved drainage and reduction of labor requirements in peak seasons

alternative land and water development strategies on such factors as cropping patterns, livestock inventory, self-sufficiency levels, and the quantity and value of imports and exports.

In summary, once the basic data were developed, the sequence of actions for each policy alternative involved three major steps:

1. Definition of alternative constraints — investment per period, emphasis on specific development activities, etc.
2. Determination of development patterns — cropland, yields, and cropping intensity — through use of a polyperiod linear programming model.
3. An expanded analysis of each alternative with KASM. Key output data were agriculture and fishery production, self-sufficiency ratios, per capita food consumption, feed grain demands, and the value of the total food and feed grain deficit.

Finally, the results of the various alternatives were compared and analyzed. The base alternative examined was a "no investment" alternative; i.e., what would happen if no further land and water development were done in Korea. Results from the other alternatives were then compared with the base run to evaluate benefits from the various levels of investment and development patterns.

This combination of analytical tools, an LP model and a sector simulation model, also led to the involvement of numerous organizations and individuals in conducting the analysis. The study originated with economists at the Agricultural Development Corporation (ADC), the semiautonomous land and water development agency of the Korean Ministry of Agriculture and Fisheries (MAF). Cooperation with the Korean Agricultural Planning Project's (KAPP) program and project evaluation analyst helped in definition of the project and development of the polyperiod LP model. Staff members from the National Agricultural Economics Research Institute/Korean Agricultural Sector Study (NAERI/KASS) modified and ran KASM. These joint efforts were not only beneficial to the land and water development analysis, but also contributed to improvements in KASM.

EXAMPLES OF THE ANALYSIS AND RESULTS

LP Model Assumptions

The polyperiod LP model was used to determine the combination of development activities — irrigation, drainage, tidal land reclamation, etc. — that would maximize production of food grains over the 1977–2001 period. The model was constructed to allow investment to occur during five-year periods coinciding with the periods covered by the five-year economic development plans. Activities were chosen by type and year to maximize production, subject to the capital and other constraints of the model. All costs were in terms of 1975 prices. Investment activities were restricted to the 1977–96 period, which allowed full production potential to be achieved by the year 2001, considering the time lag from start of construction to full realization of agricultural production potential.

A series of runs were made with varying levels of capital investment. The capital investment level was related to an annual rate of expenditure ranging from 30 billion to 145 billion won (485 won = one dollar). In 1975, the actual level of investment in land and water development projects was about 60 billion won. The highest level of spending assumed in the analysis, 145 billion won per year, provided enough investment to develop all potential areas during the 20-year period. Additional runs were made in which activities during the 1977–81 period corresponded to plans being considered by the Ministry of Agriculture and Fisheries (MAF) as a part of the drafting of the Fourth Five-Year Economic Development Plan.

LP Model Results

To illustrate the analysis, partial results from two alternatives are presented and discussed. The first, alternative A, is the "no investment" alternative, which assumes no further land and water development in Korea. This alternative is based on the assumed annual losses of paddy- and upland, no change in double-crop ratios, and yield projections for food grains. The assumed loss of 5,000 hectares of paddyland and 8,400 hectares of upland each year results in a steadily declining land base. Rice yields are assumed to reach a maximum potential of 5.05 metric tons per hectare by the year 2001. This assumption is based on adoption of improved varieties of rice and improved crop management. However, with this alternative, high-yielding varieties, such as Tongil and Yushin, are assumed to be limited to 600,000 hectares of the present paddyland, because of inadequate irrigation and drainage on the remaining paddy.

The second, alternative B, is labeled 60 billion, which corresponds to 60 billion won of investment available per year during each of the years from 1977 to 1996. The results from the LP model for this alternative are shown in Table 11. (Since under alternative A there is no investment, no improvement in the present land base, and no creation of a new land base, there are no results to include in Table 11.) The alternative B level of investment is sufficient to develop all potential areas of irrigation, subsurface drainage, land consolidation, and slopeland reclamation. However, irrigation projects are largely deferred to later periods, whereas slopeland reclamation, land consolidation, and subsurface drainage are brought in during the early periods. In addition, 71 per cent of the potential surface

TABLE 11
Investment and Development Activities from LP Model for Alternative B — 60 Billion Won per Year Investment, by Period, Korea, 1976–96

Activity	Unit	Period of Development						Percentage of Potential Area
		1976*	1977 to 1981	1982 to 1986	1987 to 1991	1992 to 1996	Total 1976 to 1996	
Total Investment	Billion Won†	73	300	300	300	300	1,273	. . .
Ways of Improving Present Land Base								
Irrigation	1,000 hectares	31	43	0	0	168	242	100
Surface drainage	1,000 hectares	0	7	0	51	68	127	71
Subsurface drainage	1,000 hectares	23	30	33	37	0	122	100
Land consolidation	1,000 hectares	50	184	80	0	0	314	100
Ways of Creating Added Land Base								
Reclaiming tideland‡	1,000 hectares	0	8	82	48	13	152	37
Reclaiming slopeland	1,000 hectares	20	115	0	0	0	135	100

*These represent planned hectarages to be developed during 1976.
†1975 prices.
‡Hectarage of tideland reclaimed is shown during the period it comes into production. However, the majority of investment requirement was generally made during the preceding period.

drainage area and 37 per cent of the potential tidal reclamation can be completed by 1996. This level of tidal reclamation creates 152,000 hectares of new paddy.

The combined effect of the amount of land and water development activities selected and their period of development under alternatives A and B provide estimates of cropland, double-crop ratios, and food grain yields, required as input data for further analysis by KASM (Table 12). Hectares of cropland, the double-crop ratio on paddy, and rice yields are all higher for the 60 billion won alternative than for the "no investment" alternative. However, yields of all other food grain crops are depressed because of the conversion of slopeland to improved upland, since the yields on converted slopeland are assumed to be only 80 per cent of yields on present upland. The increase in rice yields is due to the land improvement activities. In fact, rice yields for the 60 billion won alternative would be even higher, except that yields on reclaimed tidal land are assumed equal to the "no investment" level.

TABLE 12
Output of LP Model Used as Input for KASM,
No Investment and 60 Billion Won Alternatives,
Korea, 1981, 1986, 1991, 1996, and 2001

Item	Unit	Alternatives by Year									
		No Investment					60 Billion Won				
		1981	1986	1991	1996	2001	1981	1986	1991	1996	2001
Cropland											
Paddy	1,000 hectares	1,169	1,144	1,119	1,094	1,069	1,138	1,202	1,242	1,281	1,263
Upland*		505	463	421	379	337	631	589	547	479	437
Double-Crop Ratio											
Paddy	Perc	50	50	50	50	50	62	66	69	70	70
Upland		72	72	72	72	72	72	72	72	72	72
Food Grain Yield†											
Rice	metric tons/ hectare	4.00	4.26	4.53	4.79	5.05	4.14	4.37	4.71	5.21	5.51
Barley		2.55	2.67	2.79	2.90	3.02	2.41	2.88	2.67	2.77	2.88
Wheat		2.57	2.71	2.85	2.99	3.13	2.46	2.62	2.73	2.86	2.99
Other grains		1.51	1.75	1.99	2.23	2.47	1.41	1.66	1.88	2.09	2.30
Pulses		1.28	1.39	1.50	1.61	1.72	1.21	1.32	1.42	1.51	1.60
Potatoes		4.74	5.11	5.48	5.85	6.23	4.46	4.88	5.21	5.53	5.86

*Upland for summer grains only. Additional upland is available that is devoted to vegetables, fruit, tobacco, mulberries, and industrial crops.
†Polished grain equivalent.

KASM ASSUMPTIONS

Several major assumptions were made in using KASM. These assumptions included:

1. The basic data and relationships of KASM, such as import and export price projections, direct and cross-price elasticities, income elasticities, population projections, livestock data, and crop yield estimates were accepted. However, yield estimates for the six food grains were based on the LP solutions for each alternative, as described above.
2. The hectarage of fruit, vegetables, mulberries, tobacco, and industrial crops would never exceed the hectarage planted in those crops in 1974. Therefore, changes in the area of crops grown were largely reflected in the six food grains.
3. The Republic of Korea government would continue the policy of maintaining a constant real price for rice throughout the 1976–2001 period.
4. The government would maintain a constant real price for barley and wheat only until 1980. After 1980 wheat and barley prices would be determined by market forces.

KASM RESULTS

KASM Estimates of Cropping Patterns and Livestock Inventory

Cropping patterns from KASM for the two alternatives are shown for 1981, 1991, and 2001 in Table 13. The "no investment" alternative results in large decreases in barley, pulses, and rice, whereas wheat and potato hectarage increase. Total hectares of crops grown decline from 3.1 million in 1981 to 2.7 million in 2001. For the 60 billion won alternative, rice hectares increase, smaller reductions occur for barley and pulses, and larger increases occur for wheat and potatoes. Overall hectares of crops grown increase during the intervening years but decline in 2001.

Expansion of pork, eggs, and broiler production was fixed within KASM, so their output remained the same for all alternatives. Beef and dairy cow numbers, however, are reduced under the "no investment" alternative. Inventory levels and production of livestock and poultry were assumed equal for all alternatives in 2001 to simplify the comparisons on feed grain imports, self-sufficiency percentages, and other data. Crop production, however, was dependent on the hectarage of cropland available in 2001.

Self-Sufficiency Levels

The KASM projections show that rice self-sufficiency declines to 92 per cent in 1991 and falls to 90 per cent by 2001 under the "no investment"

TABLE 13
KASM Estimates of Cropping Pattern and Inventory of Livestock and Poultry, No Investment and 60 Billion Won Alternatives, Korea, 1981, 1991, and 2001

Item	Unit	Alternatives by Year					
		No Investment			60 Billion Won		
		1981	1991	2001	1981	1991	2001
Crops							
Rice	1,000 hectares	1,169	1,119	1,069	1,188	1,242	1,263
Barley		816	652	462	988	831	672
Wheat		49	128	230	111	309	412
Other grains		71	51	39	89	65	50
Pulses		284	206	152	354	261	195
Potatoes		176	202	205	206	246	231
Fruit		63	64	60	63	64	60
Vegetables		274	274	274	274	274	274
Tobacco		54	54	54	54	54	54
Mulberry		61	61	61	61	56	56
Industrial crops		107	94	84	107	107	107
Total Crops		3,124	2,905	2,690	3,495	3,509	3,364
Livestock							
Dairy cows	1,000 head	146	271	385	146	301	385
Beef cows		665	428	336	722	479	336
Sows		228	338	480	228	338	480
Poultry							
Hens	Million	22	33	47	22	33	47
Broilers		77	114	162	77	114	162

alternative (Table 14). Thus, Korea would require rice imports over the entire period. However, expected declines in per capita consumption and increases in yields would keep the rice deficit to around 10 percentage points.

Investment of 60 billion won per year would only increase rice self-sufficiency four percentage points by 1981 but would allow 15 and 26 percentage-point increases in 1991 and 2001, respectively. This is typical of the problem facing Korea. In the short run, increases in rice self-sufficiency because of land and water development are limited; but in the long run, large surpluses may be possible. The small impact in the short run results from the three- to five-year period necessary before reclaimed tidal land can be cultivated and another five to seven years before maximum rice yields can be achieved. But in the long run, the reclamation of about one-third of the potentially reclaimable tidal land, combined with an

TABLE 14
KASM Estimates of Self-Sufficiency Percentages of Food and Feed Grains and Value of Agricultural Exports and Imports, No Investment and 60 Billion Won Alternatives, Korea, 1981, 1991, and 2001

Item	Unit	No Investment 1981	No Investment 1991	No Investment 2001	60 Billion Won 1981	60 Billion Won 1991	60 Billion Won 2001
*Self-Sufficiency**							
Rice	Percentage	88	92	90	92	107	116
Barley	Percentage	91	87	68	103	102	94
Wheat	Percentage	6	15	24	14	31	41
Other grains	Percentage	100	100	83	100	100	100
Pulses	Percentage	89	62	38	97	70	39
Potatoes	Percentage	108	140	164	117	161	185
Food grains	Percentage	75	76	72	82	90	95
Food and feed grains	Percentage	67	64	57	73	76	74
Feed Grain Imports							
Quantity	1,000 MT	1,293	1,959	2,950	1,124	1,715	2,771
Value	Billion Won†	86	130	196	75	114	183
Agricultural Export-Import							
Exports	Billion Won†	1,864	2,245	1,923	1,870	2,235	1,932
Imports‡	Billion Won†	395	807	1,326	338	695	1,183
Balance of payments	Billion Won†	1,469	1,438	597	1,532	1,540	799
Food and Feed Grain Balance of Payments	Billion Won†	−303	−377	−538	−242	−222	−269

*Self-sufficiency compares total production to requirements for food, seed, processing, and losses. It does not include feed requirements for livestock, except in the food and feed grain self-sufficiency calculation.

†1975 prices.

‡Includes import of agricultural products for food, feed grain imports, plus imports of fertilizers, chemicals, and other inputs to produce agricultural products.

expected decline in per capita consumption after the early 1980s, suggests that Korea could have surplus rice.

Korea would not be able to be self-sufficient in *both* barley and wheat, regardless of cropping pattern or investment alternative. Yield and price effects within KASM bring about increased wheat hectarage in both alternatives shown here, but wheat self-sufficiency is still only 41 per cent under the 60 billion won investment alternative. Barley shows a 6 per cent deficit in 2001 under the same alternative, but barley self-sufficiency for food use is not expected to be a problem, providing farmers have adequate price incentives to grow barley.

Potatoes show up in surplus quantities in both alternatives. This surplus is assumed to be used for livestock feed. Pulses' self-sufficiency falls to under 40 per cent in both alternatives; but some hectarage devoted to potatoes could be shifted to pulses, if this seemed to better serve national interests.

Self-sufficiency of all food grains is never achieved with either of these alternatives. However, very substantial improvements are made with the investment alternative as opposed to the "no investment" alternative. Thus, as an aggregate quantity measure, Korea could produce 95 per cent of all food grains needed in 2001, with annual investment in land and water development of 60 billion won. But the self-sufficiency percentages for the individual commodities emphasize that substantial imports of wheat and pulses will still be needed. This underscores the need to review the monetary trade balance, as well as to look at composite food indexes on quantities.

The food and feed grains self-sufficiency measure also accounts for the feed requirements for livestock and poultry. With either alternative, Korea is expected to continue to face a major deficit of total food and feed grain demands. With the "no investment" alternative, self-sufficiency continues to decline, whereas with the 60 billion won alternative the situation remains about the same throughout the period.

Agricultural Exports and Imports

The summary projection data on exports and imports of agricultural commodities show a continuing favorable balance of payments for agricultural and fishery products. This is largely due to projected exports of fish and silk, with lesser exported amounts of tobacco and pork. In the 60 billion won alternative, surplus rice is also exported, but surplus potatoes are assumed to be used as feed grains. Agricultural imports include beef, feed grain, wheat, fruit, pulses, and vegetables, generally in this declining order of importance in value terms.

Since the primary emphasis of this study was on potential food and feed grains production, a separate balance-of-payments figure was calculated on just food and feed grains (Table 14), which indicated a deficit. However, the cost of this grain deficit would be substantially reduced from the "no investment" case if the 60 billion won investment alternative were successfully carried out. In 1981 the grain deficit could be reduced by 61 billion won, and the reduction would increase over time. The major saving occurs from the added food grain production. The data on feed grain imports show a saving of only 11 billion won in 1981, compared to the total food and feed grain saving of 61 billion won in that year.

When comparisons are made of a larger number of alternatives (11 alternatives were analyzed during the course of the study), the self-sufficiency percentages calculated by KASM allow judgments to be made of the effectiveness of various alternatives to meet future food demands. Likewise, the balance of payments measures indicate the trade balance advantages or disadvantages of the various alternatives to Korea's economic well-being.

Using data on annual savings in food and feed grain balance of payments and annual investment costs, an internal rate of return is calculated for each alternative. These rates of return provide additional measures of the economic worth of each land and water development alternative. Of course, in making final investment decisions, the Korean government considers a variety of factors in addition to the considerations presented here.

SUMMARY

Use of KASM to analyze alternative development patterns of Korea's land and water resources has provided a guide to potential supply and demand for food in Korea. The analysis is, of course, highly dependent on several key projections of yields, population, and per capita consumption. Therefore, sensitivity testing of key variables was accomplished and documented in the study report for the Korean government [45].

The approach used in the study incorporated a polyperiod LP model and KASM to define and evaluate various development strategies. A strong feature of both models is that they maintain internal consistency of the numerous relationships. Future work on land and water development in Korea will be able to use KASM with the more sophisticated technology change component (CHANGE) discussed in chapter 8. CHANGE incorporates the relationships now included in the polyperiod LP model, plus numerous other relationships. In addition, it can be used in conjunction with other KASM components or run independently, as was done with the LP model.

The full analytical report has been used by several organizations. ADC and MAF have used it for supporting material relating to preparation of budget requests for land and water development in Korea's Fourth Five-Year Economic Development Plan. It also provided a strong background for critical examination of the land and water development activities proposed by MAF for the Fourth Five-Year Economic Development Plan. In addition, the quantification of potential food grain supply and demand for Korea under various assumptions of investment in land and water development, future diets, and future yields is of interest not only to MAF and other Korean ministries but also to international lenders such as the International Bank for Reconstruction and Development [149].

Development strategies could be defined in a different manner in order to allow a more direct comparison of the specific development methods — irrigation versus drainage versus tidal reclamation, etc. But the present analysis has been useful in examining future investments in land and water development and has provided basic information that has contributed to the development of Korea's Fourth Five-Year Economic Development Plan, as well as guidelines for longer-term investment requirements.

NOTES

CHAPTER 1

1. A large volume of publications, working papers, articles, and monographs were produced by the consortium. The summary and recommendations of the project, however, are contained in [85].

2. Public Law 480, The International Trade and Development Assistance Act of 1954, as amended, includes provisions for delivery of U.S. agricultural commodities (primarily grains) to qualifying developing countries on concessional terms. Governments of developing countries can in turn generate local currency revenues through the domestic sale of these commodities to be used for development purposes mutually agreed upon by the recipient government and the United States.

3. The Agricultural Planning Project agreement between the Republic of Korea's Ministry of Agriculture and Fisheries and the United States Agency for International Development served as the framework within which the Michigan State University field activities in Korea were carried out. The MSU Korean Agricultural Sector Study team (KASS) was originally supported under contract AID/ead-184 to complete the agricultural sector analysis report [151] and the investment priorities study [50] and was later supported under contract AID/csd-2975 for further development, testing, institutionalization, and utilization of the Korean agricultural sector model. A later direct contract between the Korean Ministry of Agriculture and Fisheries and Michigan State University using AID grant funds provided technical assistance to MAF in policy analysis, agricultural outlook, program and project evaluation, and agricultural statistics, as well as assistance in KASS model and investigative capacity institutionalization and utilization. This activity was the Korean Agricultural Planning Project (KAPP). Finally, an MSU systems scientist was retained under contract AID/ta-C-1322 to provide systems science input to the indigenous KASS team for an additional 18 months after the MSU/KASS team withdrew.

4. The "KASS team" was a combined MSU and Korean team making up the Agricultural Sector Analysis Division of NAERI.

CHAPTER 3

1. This chapter draws heavily on concepts found in [151], particularly chapter 5.

CHAPTER 4

1. Differential equations contain derivatives or rates of change of system variables. Difference equations contain past, as well as present, values of system variables.

2. In this case, the range 1,900-3,000 is called a "95-percent confidence interval for the outcome." Confidence intervals for other percentages can easily be computed from Monte Carlo analysis.

3. An "operating condition" is loosely defined as sets of input and output flows that are mutually consistent, given the input-output characteristics of the producing units in the economy.

4. This step size is often called Δt, DT, or "h" in the literature of simulation models.

5. Clearly, model users (decision makers) must have had sufficient experience with the model and the real world to make meaningful evaluation possible. Part 2

CHAPTER 5

1. Currently referred to in the literature as "rural development" or "integrated rural development." Part 3

2. Useable at the bureau level within MAF.

3. Gini ratios of .255 and .270 have been calculated for income distribution in the Korean agricultural sector for 1965 and 1974, respectively. Thus, Korean agricultural sector income appears quite equally distributed and is not growing appreciably more unequal over time.

4. The *Yearbook of Agriculture and Forestry Statistics* includes production statistics on more than 100 different crops and livestock numbers for 15 different species.

CHAPTER 6

1. In mathematical/programming notation, the sequence of operations in the migration mechanism for each mode is, Part 3

Mode 1: Exogenously Specified Overall Migration Rate

$$TMIC_t = \sum_{sex=m}^{f} \sum_{age=1}^{85+} RUMV(age, sex) * POPC'_t(age, sex, farm) \tag{1}$$

$$RUMF_t = TRUM_t / [TMIC / POPC'_t(total, farm)] \tag{2}$$

Mode 2: Labor Supply-Demand Mode

$$CMIC_t(age, sex) = RUMV(age, sex) * POPC'_t(age, sex, farm) \tag{3}$$

$$EMPMIC_t = \sum_{sex=m}^{f} \sum_{age=1}^{85+} [CMIC_t(age, sex) * CIV_t(age, sex) * EAPMV(age, sex) * UEMPR_t] \tag{4}$$

$$UEMDEF_t = DLNV_t - FLN_t - UEMPR_t * \sum_{sex=m}^{f} \sum_{age=1}^{85+} EAPNV(age, sex) * CIV_t(age, sex) * POPC'_t(age, sex, nonfarm) \tag{5}$$

$$RUMF_t = UEMDEF_t / EMPMIC_t \tag{6}$$

Transfer of Migrants

$$MIC_t(age, sex) = RUMV(age, sex) * RUMF_t * POPC'_t(age, sex, farm) \tag{7}$$

$$POPC_t(age, sex, farm) = POPC'_t(age, sex, farm) - MIC_t(age, sex) \tag{8}$$

$$POPC_t(age, sex, nonfarm) = POPC'_t(age, sex, nonfarm) + MIC_t(age, sex) \tag{9}$$

where:

CIV	=	proportion of a cohort that is civilian, civilians per capita, or civilians per migrant
CMIC	=	*ex ante* estimate of net number migrating from a farm cohort, migrants per capita-year
DLNV	=	total nonagricultural labor demand, laborer-year per year
EAPMV	=	proportion of migrant cohort that is economically active, economically active persons per migrant

EAPNV	=	proportion of a civilian nonfarm cohort that is economically active, economically active persons per nonfarm civilian
EMPMIG	=	*ex ante* estimate of total employed migrants, laborer-year per year
FLN	=	net off-farm employment (labor from farm households employed in the nonagricultural sector), laborer-year per year
MIG	=	*ex post* estimate of net number migrating from a farm age-sex cohort, migrants per year
POPC	=	number of people in an age-sex cohort after migration, per capita
POPC'	=	number of people in an age-sex cohort before migration, per capita
RUMF	=	uniform adjustment coefficient for *RUMV*, dimensionless
RUMV	=	nominal profile of net proportion of a farm population age-sex cohort migrating, migrants per capita-year
TMIG	=	*ex ante* estimate of the total number of migrants, migrants per year
TRUM	=	exogenously specified overall migration rate, proportion per year
UEMDEF	=	*ex ante* estimate of the deficit between labor demand and labor supplied by off-farm employment and the nonfarm population, laborer-year per year
UEMPR	=	nonfarm employment rate, employed laborers per laborer

2. Efficiency in migration is the ratio of the net exchange of population to the total two-way flow. It ranges from zero, when the flows exactly cancel out, to one, when all movement is in one direction and the number of net migrations is exactly equal to the number of gross migrants.

3. The total fertility rate is the average number of children that a cohort of women would bear were each woman to complete her child-bearing years for a given age-specific fertility schedule.

4. Primary sources include FAO Korean Association, *Human Nutrition Requirements in Korea, Recommendations by Ministries of Health and Social Affairs and Science and Technology*, in cooperation with the Korean Nutrition Institute, 1975. The calorie recommendations, in turn, were based on (a) Report of a Joint FAO/WHO Ad Hoc Expert Committee, "Energy and Protein Requirements," FAO Nutrition Meetings Report Series No. 52 (Rome: FAO, 1973); and (b) World Health Organization, "Handbook on Human Nutritional Requirements," WHO Monograph Series No. 61 (Geneva: World Health Organization of the United Nations, 1974).

CHAPTER 7

1. This assumes, of course, that increases in demand will, except possibly in the very short term, be supplied domestically rather than from imports.

2. Derived from 1970 household survey [101, 107] and input-output data [16] and considering only interactions of intermediate input and consumption demands.

3. In Figure 19, the production component is an aggregation of the technology change and resource allocation components.

4. Of the other five sectors, consumption in two (agriculture and food processing) is determined in the KASM demand component, and final consumption of the other three (chemical fertilizer, trade, and construction) is assumed to be zero.

CHAPTER 9

1. The price vector, generated endogenously by a simultaneous market model subject to a budget constraint, is in fact the basic dynamic link in the model. Previous applications of recursive programming with single demand equations were presented by Mudahar [136].

2. For the theoretical background of this approach and applications to development planning, see, for example [10, 36, 37, 39].

3. In a regional mode this would correspond to one regional block of the matrix in Figure 30.

4. For problems of farm mechanization in Korea, see [117].

5. The approach is based on [23].

6. More precisely, the model contains a distributed lag submodel to compute the cohort structure of perennials.

CHAPTER 10

1. The only functional difference between the nonfarm and the farm demand components is an "elasticity expansion" parameter. This changes all nonfarm demand elasticities proportionally to ensure that the projected levels of prices and demand agree with the projected total expenditure (income constraint). For farm demand, the income constraint is maintained by computing nonfood consumption as a residual.

2. This is the percentage change in, for example, rice consumption for a 1 per cent change in rice price, assuming all other prices and income do not change.

3. These are the percentage changes in, for example, wheat, barley, and potato consumption for each percentage change in rice price, assuming all other prices and income do not change.

4. In mathematical terms, the nonfood cross elasticities are

$$\varepsilon_{nf} = -(\Sigma_j \varepsilon_j + \varepsilon_y)$$

for each food commodity, where ε_j is the elasticity with respect to the j^{th} price and ε_y is the income elasticity.

5. See [164] for the derivation of the values of the limits currently used in DEMAND.

6. For a survey, see [181]. In particular see [120, 158, 159].

7. Adjustments reflecting truly unprecedented events are legitimate and required. But a change reflecting "expert opinion" or because "it doesn't look right" should have been specified as prior information; and Bayesian, rather than classical, statistical methods should have been employed to estimate the relations. For example, see [182].

8. The equation is,

$$(q - T/2)^2 = \frac{(q_0 - T)}{\eta} y \frac{\partial q}{\partial y} + (T/2)^2$$

where q is per capita consumption, y is income, and the parameters are T, the consumption limit; η, the initial income elasticity; and q_0, the initial consumption level. This is derived from the following equation of

$$\varepsilon(t) = \eta(q-t)/(q_0-T)$$

where $\varepsilon(t)$ is the income elasticity at time t; i.e., $\frac{\partial q}{\partial y} \cdot \frac{y}{q}$.

Part 3

CHAPTER 11

1. After the groupings were first identified and used in the model, it became desirable to separate the resource allocation decisions for vegetables into summer, fall, and winter vegetables. Similarly, the resource allocation model disaggregates potatoes into sweet and white potatoes. These three supply activities are then added together for interaction in the demand-price-trade component.

2. However, for such purposes as estimating base-period prices and average nutritional value, each commodity within the group is weighted according to its base-period quantity.

3. A detailed description and critical analysis of the Korean agricultural data system are contained in [35].

4. Data are considered consistent when (1) the same variable is measured in exactly the same way over time, (2) different measures of the same variables are identical, and (3) the sum of various component parts of a variable equal the total derived by an alternative method.

5. The estimation procedures employed are described in [164].

6. See Alan R. Thodey [164], chapter V.

7. This is reported further in chapter 13.

CHAPTER 12

Part 3

1. Other studies had already investigated investment options in crop improvement research and extension. For example, see [50]. Indeed, this study, which used KASM as one of its analytical tools, provided the analytical basis for decisions by the Korean and U.S. governments to finance and carry out a crop improvement research program in Korea.

2. Indexes of national average rice consumption are not plotted since the policy alternatives are assumed to affect directly nonfarm consumers only.

3. Since Korea's domestic rice price is about double the world price, it is assumed Korea cannot export surpluses. If government export subsidies were given to encourage exports, stocks would not rise so high.

4. Prices are constrained to fall no more than 5 per cent per year *in real terms*. If a 10 per cent inflation rate is assumed, this would mean prices are constrained to rise *at least* 5 per cent per year in nominal terms.

CHAPTER 14

1. For more background information on grain policy in Korea, see [90, 131, 134, 169, 170]. Part 4

2. Computer costs for a run of the GMP vary considerably depending on the length of run, size of simulation increment, amount of analysis and output required, the particular computer used, etc. The test runs described at the end of this chapter cost approximately $25 on the MSU Control Data 6500 computer. Cost in Korea on a CDC Cyber 70 would be somewhat less for the same runs.

3. Production costs for high-yielding "Tongil" varieties exceed traditional variety costs by about 20 per cent. In 1974, Tongil yield was estimated to be 34 per cent greater than traditional varieties, giving a positive influence on the diffusion process with 40 per cent more area going into Tongil production in 1975 [156]. In 1972, however, Tongil yields suffered from bad weather conditions and exceeded ordi-

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